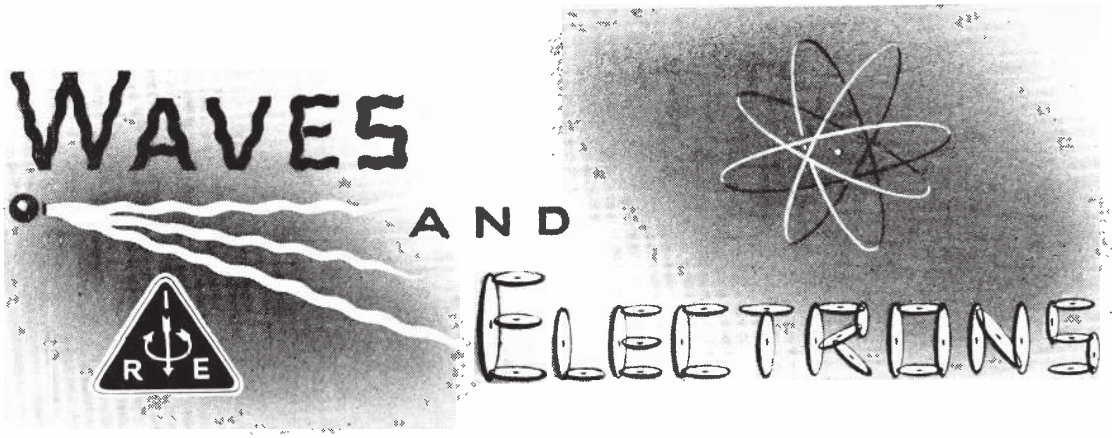

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The following editorials appeared in a preliminary issue of WAVES AND ELECTRONS in July, 1945. They remain pertinent and are accordingly here reprinted, essentially in their original form.

Waves and Electrons

A Publication of the I.R.E.

ALFRED N. GOLDSMITH, EDITOR

IN PLACING before members of The Institute of Radio Engineers and readers of its PROCEEDINGS of the I.R.E. this issue of a new publication, WAVES AND ELECTRONS, some historical and evolutionary information is properly included.

A third of a century ago, a small group of "wireless engineers" gathered with a common thought and intent. Their thought was that the nascent "wireless industry" had before it a future of untold promise; that there should be substituted in the corresponding technical field for mere trial-and-error and mysterious and confusing secrecy the frank expression of widely disseminated scientific truth; that to these ends an ethical attitude should be encouraged among the practitioners of the new profession of radio engineering; that the *common* good of the radio-engineering profession was not only the best course but also the most practical aim for farsighted workers in that field; and that to achieve these worthy and socially productive aims it was essential that there be formed a new radio-engineering society, strong in purpose, effective in execution, and worthy of the loyal and willing support of its members. Their intent was to form such a society and to give it their best thought and effort.

It was not an easy task that they voluntarily assumed in those days which are now so remote as to seem almost formless and incomprehensible to the modern and specialized worker in our field. Human reactions and frailties combined with material and financial difficulties to challenge the aspirations of those men. But the obstacles were ultimately surmounted and thus there was born our Institute of Radio Engineers.

Today, it is truly *The* Institute of Radio Engineers, the living embodiment of the professional aspirations of its members and their chosen medium for co-operative expression of their technical discoveries, plans, and proposals. Where once a handful gave their support to the Institute, there are now thousands; and thus The Institute of Radio Engineers in its fourth decade enjoys a membership far advanced into its second ten-thousand. It is world-wide in scope; fortunate in its organic unity with its many Sections in three countries; and properly encouraged by the work and standing of a national I.R.E. Council in a friendly country other than that of its origin. Its long-established publication is a recognized medium of consistently maintained standing. Its repute stands as high as its future seems bright.

For the latest decade, it has become clear that the original scope of the Institute has naturally expanded far beyond its former boundaries. The radio arts have been the ancestors of a host of technical applications of ever-increasing engineering and industrial interest and human significance. These later developments have come to be known by the generically descriptive term of "electronics"—a convenient though scientifically vague designation. Perhaps the most distinctive attribute of electronic methods is the utilization, somewhere in the corresponding systems, of electrons freed from material paths, and flexibly and instantaneously controlled to produce the desired effects.

The chosen publication medium of the I.R.E. members up to this time has been the PROCEEDINGS of the I.R.E. Its pages have literally been the history of the radio and allied arts. When its successive volumes are scanned, it is found that they have presented unobtrusively, but none the less comprehensively, the basic principles, devices, and methods of electronics as well as radio. Of late, this fact has appeared with ever-increasing clarity. It has seemed fitting therefore to present on the cover page of recent issues of the PROCEEDINGS a definite statement of the scope of that publication and the more detailed topical headings covering its usual contents. This accordingly has been done.

But another type of differentiation or evolution in the publication policy and procedure of the Institute now seems appropriate. This involves the addition to its publications, in one form or another, of an assembly of material of more general, historical, or tutorial nature and in some instances of particular and timely technical interest. This new material will also deal with the communication and electronic arts.

Communication of intelligence is essentially based on waves. Whether these be the pressure waves of touch and sound, or the electromagnetic waves of light and perhaps of neural messages, they constitute our basic means of communication and thus our essential contacts as individuals with the outside universe and with each other. Electronics, as stated, is functionally an expression of electron behavior and control. And, most remarkable of all, the electromagnetic wave and the electron seem to be but two aspects or modes of action of the same underlying and fundamental unity. What could therefore be more expressive of our cosmos and its contacts with humanity, as well as certain of the most powerful agencies now available for human communication and advancement, than the title of the new I.R.E. compendium: WAVES AND ELECTRONS?

In the hope and belief that The Institute of Radio Engineers will continue to be the primary repository and dissemination means of the engineering wisdom and accomplishments of its members in war and peace, and that its publications will ever be an agency promoting a brighter and more fruitful future for mankind, there is thus added to the activities of the Institute the issuance, according to an appropriate schedule, of additional material the title of which amply indicates the scope and means of the electronic and communication fields.

Electronics and Communications

Their Present and Future

W. L. EVERITT, PRESIDENT, 1945

COMMUNICATION engineering has ever been the originator of new applications of electricity and enterprises associated with it. The first commercial use of electricity was in the telegraph, and more than one electrical society was either established or fostered and encouraged by the early telegraph engineers. An early commercial application of electric currents generated by changing magnetic fields was the telephone of Bell, and the first applications of electronics were by Fleming and de Forest to the detection of radio waves

Because communication engineering has many applications for small-current phenomena, it is usually the field in which new discoveries in electrical physics find their first application. Because it deals with such large ranges in power, impedance, and frequency, it requires a careful approach to the study of its phenomena to make sure that *conclusions* which may be drawn from particular experiments are based on an understanding of broad general principles.

All energy is transmitted by waves. When we apply a force (mechanical or electrical) to the driving end of a transmission system, the corresponding response is not felt immediately at the receiving end, but there is a finite time required for the effect to be propagated. If the force changes slowly, or if the transmission medium is stiff (as for instance in the connecting rod of a low-speed engine) the designing engineer pays little attention to the wave phenomena, or the finite time required for transmitting the disturbance. As the frequency is increased, approximations which neglect wave action are no longer valid.

In the early telegraph circuits, the transmission of direct currents over open wires seemed simple and straightforward. But as time went on, the telephone was invented, the lines became longer, cables with less stiffness were introduced, and higher frequencies were employed. Signal distortion became important, and a more complete theory of the travel of electrical waves along guided paths became necessary.

Coulomb studied the properties of electrons at rest (even though he did not know of their existence) and his law is the basis of our knowledge of electric fields. Ampere studied the properties of electrons in *motion:* and his law is the basis of our knowledge of the magnetic field produced by electric currents. Maxwell studied the properties of the acceleration of electrons and laid the basis for the initiation of those dynamic electric fields which do not require charges on which their lines of force terminate. He showed that the transmission of electric energy is not necessarily confined to the highways along which electric currents flow. Edison, and his successors in the electronic field, showed also that even electron currents are not necessarily confined to metallic highways. de Forest and Arnold showed the advantages for electronic traffic control of these nonmetallic gateways enclosed in the vacuum tube. From these foundations we see that our understanding of all electric phenomena is based on our knowledge of the principles connected with waves and electrons.

The war has shown what concentrated research and development and adequate financing may accomplish. The future of electronics and communications is bounded only by the ability of man to understand their principles and convert them to his uses. The engineer is essentially a builder and not a destroyer, and so the arrival of peace will stimulate him to even greater endeavors in the days to come if he is given the tools with which to work.

The primary function of The Institute of Radio Engineers is one of education. Since its organization the PROCEEDINGS has recorded most of the major advances in the electronic and communication art. It will continue to do so. As a result of the information dispensed in its pages many new developments have been initiated. The applications of these developments are spreading into many areas outside the field of communication. The expansion of principles, techniques, and applications are such that no longer can the individual engineer or scientist be well versed in them all. Therefore, a new educational function is required of the Institute in coordinating and summarizing the growth of knowledge and its application. To provide for this new function, either the recording of new advances must be restricted (which is unthinkable) or our publication activities must be expanded. I regard the advent of WAVES AND ELECTRONS as an historical event in the progress of the Institute whose significance will be recognized as the years go by and its contributions to the electrical arts expand and become of assitance to the professional workers in all the fields which it serves.

Kaiden-Kazanjian Studio

Benjamin E. Shackelford

Board of Directors—1945–1947

Benjamin E. Shackelford was born on August 12, 1891, in Richmond, Missouri. He received the A.B. degree in 1912 and the A.M. degree in 1913, both from the University of Missouri. In 1916, he received his Ph.D. from the University of Chicago.

From 1912 to 1914, Dr. Shackelford assisted in the physics department of the University of Missouri, and in the summer of 1925 was the first Brush Research Fellow at the Nela Research Laboratory. The following year, he joined the staff of Westinghouse Lamp Company, where his activities included work in illumination and incandescent lamp physics. His direct connection with radio began in 1916 when he undertook the engineering development of radio tubes for the company. He became manager of the radio engineering department in 1925, and his work with Westinghouse continued for approximately five years.

He became a member of the manufacturing department, radiotron division, of the Radio Corporation of America at Harrison, New Jersey, in 1930, and in 1934 was appointed manager of the patent department, activities of which included the operation of foreign technical agreements. After serving as manager of the company's foreign license service, Dr. Shackelford transferred to New York where he became assistant to the director of research and later to the chief engineer. In 1942, he was appointed engineer-in-charge of RCA's frequency bureau. Since 1944, he has been assistant to the vice-president in charge of RCA Laboratories, and manager of the license department of the RCA International Division with particular responsibility in the field of international activities.

Dr. Shackelford is a member of the American Physical Society, the Optical Society of America, the American Institute of Electrical Engineers, the Franklin Institute, the American Association for the Advancement of Science, Sigma Xi, Gamma Alpha, and Alpha Chi Sigma. He joined the Institute of Radio Engineers as an Associate in 1923, transferred to Member grade in 1926, and became a Fellow in 1938.

Preparation and Publication of I.R.E. Papers*

HELEN M. STOTE†

Summary—The various steps in the preparation of manuscripts for publication in the PROCEEDINGS of the I.R.E. and WAVES AND ELECTRONS as well as a short explanation of the handling of papers after they are received by the Institute, are outlined. The mechanical preparation of papers and the various stages through which they progress will be treated.

I. INTRODUCTION

TO SOME contributors to the pages of the PROCEEDINGS,[1] certain of the policies and procedures of the Editorial Department might seem either unnecessary or without sufficient justification. Yet, present methods of handling papers are based on long experience and on many requirements, some of which are not obvious. Further, it has always been the wish and desire of this Department to be logical, fair, and consistent in its treatment of all manuscripts submitted for consideration so that the best relations may exist between author and reader. This paper is presented in the hope that many questions which may confront or even puzzle authors may be answered.

Every publication has a broad underlying editorial policy which may differ radically from that of other periodicals, and even from those in the same field. Such policies promote coherence and consistency in style and form and thus reduce confusion or annoyance to the reader. Some few authors go so far afield from a desirable treatment of material that intensive editing of their papers is necessary (to say nothing of the required application, at times, of the simple rules of grammar and composition). Certain fundamental rules are also applicable to illustrations. It is obviously necessary that figures be presented in a clear form or the resulting printed page will lose in value to the reader.

It is one of the aims of the Institute to ensure the technical quality and originality of the papers appearing in its PROCEEDINGS. Accordingly, every manuscript received by the Editorial Department of the Institute is scrutinized by at least three members of the Papers Committee and one or more members of the Board of Editors before it is accepted for publication (or declined as unsuitable for the PROCEEDINGS). These readers carefully examine and study each paper and judge it on its likely value to the membership. Their reviews are of great benefit to the author whether the paper is finally accepted or not, for fundamental or less serious errors in manuscript are not infrequently caught, thus avoiding damage to the reputation of the author and impairment of the high quality of the PROCEEDINGS.

* Decimal classification: R053. Original manuscript received by the Institute, August 31, 1945.

† Publications Manager, The Institute of Radio Engineers, Inc., New York, N. Y.

[1] In this paper "PROCEEDINGS" means PROCEEDINGS of the I.R.E. and WAVES AND ELECTRONS.

II. THE MANUSCRIPT

Papers should be submitted in triplicate to the Editorial Department, The Institute of Radio Engineers, Inc., 26 West 58th Street, New York 19, New York. A complete set of illustrations should accompany *each* copy of the manuscript, since each paper is to be read by each of the three selected members of the Papers Committee. When three copies of the manuscript are submitted, they can go to the readers simultaneously. If only one or two copies are submitted, it is necessary to wait until they are returned to the Editorial Department before they can be forwarded to additional readers. This, obviously, delays the processing of the manuscript and the date of its publication.

The manuscript should be typed on white paper, regular letter size ($8\frac{1}{2}\times 11$ inches), double-spaced, and with margins about three quarters of an inch to one inch in width. Only one side of the paper should be used, and each page of every copy should be carefully checked to be certain that it is completely legible and without errors or omissions. Blueprint copies and silver-print copies are not desirable because, in the mechanical editing process, it becomes necessary to use a white pencil on the blueprints or a pen on the silver prints, and the clarity of the marked corrections leaves much to be desired.

The paper should have a short title, preferably not longer than five or six words. After the title, the name of the author should follow immediately, and a footnote reference should give the author's university, governmental, or business affiliation and location. If the paper has been presented at a meeting of any kind before any organization, this should be noted either in the footnote or in the letter of transmittal which accompanies the manuscript. The name of the meeting, the place, and the exact date should all be incorporated.

The author should state in his letter of transmittal of the manuscript any plans for the publication of his paper other than in the PROCEEDINGS. He should also inform the publicity division of his organization that it is the policy of the PROCEEDINGS not to publish any paper which has appeared in English in any publication having a substantial circulation among the readers of the PROCEEDINGS. The purpose of this policy is to avoid duplication of effort and waste of material, properly to conserve the funds of the Institute. Further, if the author is aware of any earlier partial or complete anticipation of publication in any language of the work described in his paper, he should state that fact early in his paper to avoid possible confusion or misunderstanding.

A short summary should precede the body of the

paper explaining the context in brief. Footnote references and equations should not appear in the summary.

It is desirable to have division headings, but to keep the number of these within reasonable limits. Subheadings are frequently confusing to the reader and should not be employed unless absolutely necessary.

At the end of the paper, all of the captions for the figures should be typed on a single sheet. Only the first word of each caption should be capitalized. The figures themselves should not carry these captions, but only an identifying figure number. It is highly desirable that the name of the author be on each figure. This identification is particularly helpful to the Editorial Department when the manuscript and illustrations are sent in separately, and also in identifying the proper paper when the illustrations are sent to the engraver to be made into cuts for the printer. Unrelated figures should not be divided into parts unless each part is an integral part of the whole figure. All figures should be numbered in chronological order according to the first reference made to them in the text.

The footnote references should give the full name of the author, the title of the paper, the publication in which it has appeared, the volume number, the beginning and concluding pages, and the month and year of the publication. As an example: Dorman D. Israel, "Looking forward in engineering education," PROC. I.R.E., vol. 23, pp. 353–355; June, 1945. References to books should give the name of the author, the title of the book, the name of the publisher, and the city, date, and year; where a particular page or chapter is referred to, this should be added. For example: V. K. Zworykin and G. A. Morton, "Television—The Electronics of Image Transmission," John Wiley and Sons, New York, N. Y., 1940, pp. 370–374. The editorial readers of the PROCEEDINGS feel that while in some cases a bibliography is desirable, generally speaking, it is better to indicate references within the body of the paper by means of footnotes which appear on the same page. In some cases, such as in an historical paper, a full bibliography is more desirable. Footnote references should appear in chronological order without exception. Numerals should be used in place of asterisks or daggers.

III. ILLUSTRATIONS

Wherever possible, illustrations should be submitted on sheets $8\frac{1}{2}$ inches by 11 inches (which is regular letter size), since the standard file cabinets used by the Editorial Department and others readily accommodate this size folder. Where larger sized paper is used, or where drawings are large and difficult to handle, there is the risk that both the manuscript and illustrations may be damaged in handling. Small illustrations or photographs may be lost if not attached to the $8\frac{1}{2}$- by 11-inch sheets. Extremely large illustrations are awkward to mail and are often a cause of trouble to the author and the publisher. (In some cases, the engraver makes an extra charge for the reduction of very large figures.) It should be kept in mind that most illustrations in the PROCEEDINGS are reduced to a maximum width of $3\frac{1}{4}$ inches. In some extreme cases, they are made larger, but in the interest of economy in paper and in cost, the sizes are kept to the named dimension wherever possible. Therefore, all printing and symbols on the illustrations should be of such a size that, when the figure is reduced to $3\frac{1}{4}$ inches or slightly less in width, the printing will be clear and distinct and the symbols legible. A suggested lettering size is given in the last paragraph of this section. Printing and symbols should be of the same size on all figures in any one group. Drawings should be done with black ink on tracing cloth or white paper. They should not be done with fountain-pen ink which may smear, fade, or reproduce badly. Where graph paper is used, it is desirable to use the kind which has a light-blue, cross-hatched background with the major divisions in red. In the photoengraving process, the blue drops out completely, and the red appears as black. (See Fig. 1.) Some authors submit figures on paper with yellow, green, brown, orange, or red cross-hatched paper. Such backgrounds reproduce in black with confusion and blurring of lines and lettering. (See Fig. 2.) A search was made for log-log paper with blue backgrounds and red major divisions, but the two leading companies which handle these papers do not manufacture log-log paper in these combinations. Therefore, where this paper is to be used, it is desirable to plot the chart on tracing cloth or white paper with only the major divisions indicated. Where this is impossible, and where the printing appears

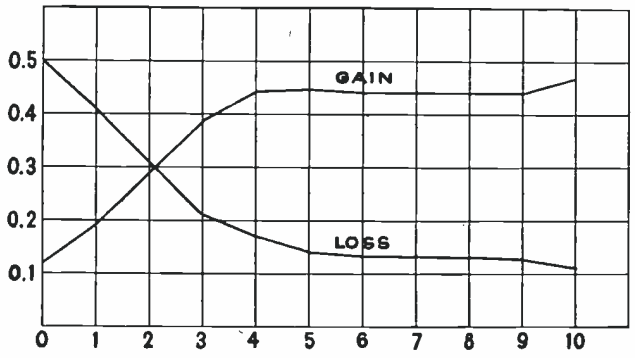

Fig. 1—Drawing made with black ink on blue cross-hatched paper with major divisions in red.

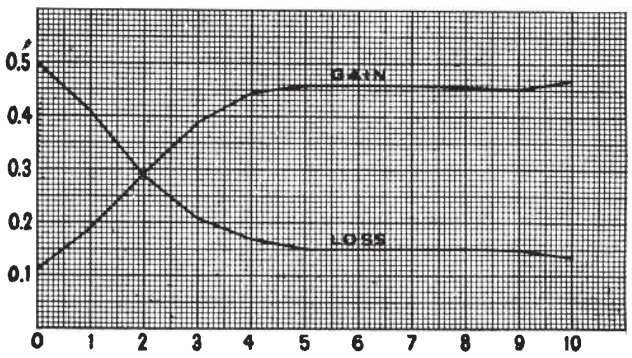

Fig. 2—Drawing made on cross-hatched paper with yellow, green, brown, orange, or red backgrounds.

on the figure itself, the author should copy the printing on small pieces of white paper and carefully paste them in the required places. When the cut is made, these letters will appear on little white "islands" and will be legible and sightly. However, one danger of this practice is that these small pieces of paper frequently fall off and are lost.

Photographs must be sharp in detail and on glossy paper. While matte-finished pictures are more artistic, much detail is lost in the photoengraving process. Any printing which necessarily is included on a photograph should be directly on it and not carried over into the white margin of the picture. The reason for this procedure is one of economy, for unless this method is used, the corresponding cut has to be made, in photoengraving terms, as a "combination half tone," and the cost is approximately twice that of an ordinary half tone.

Some commercial companies have a practice of printing a file number on the illustrations. Wherever possible, this is eliminated from the finished production; if it is impossible to "crop" it from the picture, it is necessary to have an artist airbrush it out. This extra work, of course, adds to the time element and to the cost of the cut, and is to be avoided wherever possible. Sometimes, holes are punched in the photograph itself, and these, too, are eliminated from the figure when the cut is made; or, where they interfere with the illustration itself, it is necessary to have the artist patch these holes. This patching process also adds to the cost of the cut and is not desirable. At present, the Institute does not employ an art staff to handle such special matters. Accordingly, it is necessary to send out all such work to be done by an artist. Sometimes, authors send in a rough pencil sketch. In these cases, it is necessary to return the drawing to the author for redrawing in an accepted form, and this, of course, slows up publication. Illustrations should not be mounted on heavy bristol board since such material is awkward to mail and greatly increases the postage cost.

For a drawing which is 8 by 10 inches, the lettering should be one quarter of an inch high and all other material in proportion. Figure numbers and captions should never be included on the figure itself. The author should submit with his manuscript three extra copies of his illustrations, such as blueprints or photostatic copies, so that these may be sent to the readers. He may indicate that he will supply the original drawings when he has been notified of the acceptance of his paper for publication, or he may send the original drawings at the time of submission in which case they will be kept in the files until needed.

IV. Mathematics

Some authors are so familiar with their own handwriting and with the symbols in the equations that they do not make these as clear or definite as could be desired. The author should, therefore, take extreme care in writing his equations so that there will be no doubt of his meaning in preparing the manuscript for use by the printer and typesetter. To avoid possible confusion, it is well for the author to write out the name of any new or unusual symbol on the margin of the paper. In the case of complex mathematical equations, he should insert parentheses, braces, and brackets where needed.

The equation number should be enclosed in parentheses and put at the far right of the equation. Equations should be numbered consecutively. Some authors start to renumber their equations with each section, or with each appendix. This practice is confusing to any later author who may use the paper as a reference.

Decimals should be preceded by a zero, such as 0.04, rather than .04.

V. Abbreviations

In every field, certain abbreviations and even slang terms are used. These are quite right and proper in their ordinary usage, but are believed to be unsuitable for the pages of the Proceedings. Slang and "shop talk" therefore, should not be employed. All words should be written out, (such as decibels, microvolts, megohms, and the like). The underlying reason behind this procedure is one which, until recently, was less important than usual, but is nevertheless fundamentally sound. The Institute of Radio Engineers is an international organization and has members in every part of the world who derive great benefit from the Proceedings. Many of these members have a reading knowledge of English, but may not be familiar with abbreviations or peculiarly idiomatic or popular expressions, and therefore may become confused in reading papers published in these pages unless they are formally presented. For the benefit of our foreign readers and our younger student members, the Editorial Department adheres to the strict policy of writing out abbreviations. The only exception to this is that, in tables, abbreviations occasionally may be used. Also, because of the long-established custom in all textbooks and journals, figures are always referred to as "Fig. 1," "Fig. 2," etc.

VI. Contributors Section

In the Contributors section, there are published formal portraits of authors. An attempt is made to keep the portraits reasonably uniform in size so that the page may present a pleasing appearance. The accompanying biographical sketch should include the author's name, date and place of birth, degrees received and dates awarded, institutions which granted them, places and dates of employment, and his affiliation with other professional, honorary, and scientific societies. A careful reading of several published biographical sketches should prove helpful in the preparation of this material.

VII. Processing a Manuscript

The author may wish to know what happens to his manuscript after it has been sent to the PROCEEDINGS for consideration.

As stated, the manuscript preferably is submitted in triplicate, and three sets of figures (blueprints, photostats, etc.), should accompany it, together with a complete set of original illustrations. The author should be certain that the manuscript is complete and he should not send additional material to be inserted later. Receipt of the manuscript is acknowledged to the author by the Editorial Department; a card is made out listing the name of the author, the title of the paper, and various other data, which card is kept active and up to date in the Editorial-Department files until final disposition has been made of the paper. A form is filled in and sent with one copy of the manuscript to the Editor for inspection. He examines the manuscript and selects the readers on the Papers Committee and the Board of Editors to whom the manuscript should be sent for review. The readers on the Papers Committee are skilled and recognized specialists in the field covered by the paper, and the member of the Board of Editors has a broad, over-all knowledge of both the field of the paper and the value of the submitted material to the PROCEEDINGS. Every attempt is made to select a variegated and impartial group of readers.

If the Editor finds that the publication of the paper might prove detrimental to the national interest, he sends the manuscript to a suitable referee or a government department for a decision in the matter. If, in the opinion of the reviewer, the manuscript falls into this class, it is returned to the author with such a notation.

When the paper appears on the desk of the Technical Editor, it is routed to the three designated members of the Papers Committee for review. When these three reviews have been received by the Editorial Department, they are sent, together with one copy of the manuscript, to the designated member of the Board of Editors. He then gives his opinion, and the whole file is sent to the Editor. The preceding steps are carried out by the Technical Editor. According to the reports of the readers, the Editor has three courses open to him: to accept the paper as it stands; to return the paper to the author for revision; or to classify it as unsuitable for publication in the PROCEEDINGS.

When a paper is accepted, the author is so informed, and any missing material is requested, such as a summary, original illustrations, captions for the figures, and a biographical sketch and photograph of the author. Where the author has previously had the last two items published in the PROCEEDINGS, he is informed of the date of their publication and requested to submit any changes which he desires to have made.

The paper is then mechanically edited. The type sizes are indicated for the printer, footnotes put in order, figures prepared for the photoengraver, and cuts made. The engineering correctness of the language and equations is carefully checked by the Technical Editor. The manuscript is edited for spelling, and the grammar is carefully checked. The Editorial Department of the PROCEEDINGS endeavors to make each paper as nearly grammatically correct as is possible, and relies for this purpose on the Second Edition of Webster's New International Dictionary, Unabridged; the Century Collegiate Handbook; and the Manual of Style, published by the University of Chicago Press. To any reader of the PROCEEDINGS, it is evident that hyphens are abundantly used. This conforms to the rules laid down by the previously mentioned books and is not arbitrary. Likewise, the usage found in the PROCEEDINGS of writing non-, semi-, super-, etc., words solid is in accordance with the spelling found in Webster's dictionary.

When the manuscript has been edited and the cut proofs checked against the original figures and found to be in good order, the paper is then sent to the printer. He sets it in type and returns a galley proof to the Editor, the Technical Editor, the National Bureau of Standards, and two copies to the author. The author inserts his corrections on one of the proofs and returns it to the Editorial Department, retaining the other copy for his files. After the galleys have been read by the Editor, Technical Editor, Department proofreader, the author, and the printer, all corrections are made on one master galley to which is added the decimal classification assigned by the National Bureau of Standards. This classification is inserted in the first footnote of the paper, which carries an asterisk instead of a numerical designation. It is not necessary for the author to trouble himself with the decimal classification.

The scheduling of papers for publication is carried out systematically to produce balanced, instructive, and interesting issues of the PROCEEDINGS. When this has been done, all of the manuscripts scheduled to appear in that particular issue are returned to the printer, together with the additional material which appears in the section of the magazine following the technical papers. This material consists of the Contributors section, book reviews, and miscellaneous items of interest to readers of the PROCEEDINGS. The printer makes all of the necessary corrections and returns page proofs to the Editorial Department. The Associate Editor and Technical Editor check the page proof, and the Editorial Department painstakingly goes over the dummied and corrected material, comparing it with the corrected page proof submitted. All corrections are checked, and final errors are noted for the printer. This material is then returned to the printer; after he has made the additional corrections and changes, the issue is ready to go to press.

VIII. Reprints

When the author receives his galley proof, he also receives a reprint-order blank and a blank for the return of his used material. Both of these should be filled in

promptly and returned with the corrected galley proof. Reprints must be ordered at the time of publication, since type may be broken immediately after the issue is run off the press. Reprints are run at the same time as the issue, but are not gathered together, trimmed, and mailed until some time later. The reason for this is that the most logical time to print the reprints is when the issue is being run. However, since reprints are manufactured on a fill-in and low-cost basis, it is not possible to have them completed immediately. In normal times, reprints were usually shipped within thirty days after publication, but, because of manpower shortages, reprints may not be shipped until sixty days after publication. The reprint bill is received some time after the copies have been shipped, and the author is then billed for the reprints.

IX. Conclusion

It is hoped that the above discussion will clarify many problems in the minds of our authors, whether they have already contributed to the pages of the PROCEEDINGS or are contemplating writing a paper. The author should bear in mind that, in addition to his paper being technically sound, it is most desirable that the manuscript be presented in a clear and concise manner; and that, physically, its appearance be attractive, (that is, clean typing on white paper, wide margins, and equations carefully written or typed), figures in good order, and footnote and figure references presented chronologically. The paper is then far easier to review and does not present a later mental hazard to the PROCEEDINGS readers. It is reasonable to presume that a carefully prepared paper, well presented, enables more prompt action in the editorial processes than one less carefully prepared.

If the prospective author will carefully study an issue of the PROCEEDINGS, he will note the results of the procedure here described. A little thought and time spent on such a survey will likely be valuable to him and, incidentally, will greatly assist the editorial readers and the Editorial Department.

The Editorial Department is at all times eager and anxious to co-operate with the author, and any questions which he may wish to ask will be answered as promptly as possible. It is deeply appreciative of the friendly and effective help of many of the authors. It exists to work for the authors and the readers and the PROCEEDINGS of the I.R.E. and WAVES AND ELECTRONS is their magazine. The Editorial Department is here for no other purpose than to serve them.

An Ultra-High-Frequency Radio Range with Sector Identification and Simultaneous Voice*

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Summary—**The primary purpose of a radio range for aircraft use is to provide a reliable indication to the pilot of an airplane as to his location with respect to a predetermined course. In addition, it is very desirable to identify quickly and positively the sector in which the airplane is at any given time; i.e., whether it is east or west of an east-west radio-range station. Voice radiated omnidirectionally is also desirable for ground-to-plane communication.**

The basis of the radio-range design described herein is the two-course localizer used in instrument landing. A group of three loop radiators provide two overlapping mirror-image patterns modulated at 90 and 150 cycles, respectively. A cross-pointer instrument, the vertical pointer of which is actuated differentially by the 90- and 150-cycle modulation, provides the pilot with the necessary information for orienting his plane.

A second pair of outside radiators, similar but at right angles to the first group, in conjunction with the center radiator, which is common to both the aural and visual systems, provides a keyed signal for aural sector identification. Except for the carrier radiation which is common to both the aural and visual signals, the two systems are entirely independent. Voice is radiated only by the center antenna.

The theory of the antenna system is discussed in this paper, paying particular attention to the problem of interaction between the aural, visual, and voice radiating systems. The various stages of development leading up to the final range installation at the Civil Aeronautics Administration Experimental Station in Indianapolis are given.

Introduction

THE PRIMARY purpose of a radio range for aircraft use is to provide a reliable aural or visual indication to the pilot as to his location with respect to a predetermined course. In addition, immediate and positive identification of the sector in which the airplane is at any given time; i.e., whether it is east or west of an east-west radio-range station, along with voice radiated equally in all directions from the station for communication purposes, is a very desirable feature.

The ultra-high-frequency radio-range with sector identification and simultaneous voice represents a highly specialized recent development to fulfill the above requirements. It seems desirable, therefore, to precede its

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description with a brief discussion of past developments in this field.

Four-Course Range and Two-Course Localizer

1. Four-Course Radio Range

The conventional four-course range, whether of the low-frequency type used throughout the country, or the ultra-high-frequency type, has a radiation characteristic similar to that of Fig. 1. Two mutually perpendicular figure-eight patterns are radiated successively, one keyed with characteristic identification A(· —) and the other N(— ·), the two signals being interlocked. The course is determined by the merging of the two interlocked 1020-cycle signals. A steady 1020-cycle tone informs the pilot that he is in the "on-course" region; a definite A(· —) or N(— ·) indicate the side of the course on which the airplane is flying.

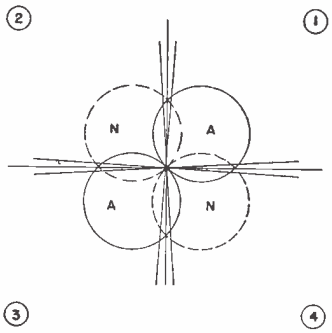


Fig. 1—Four-course radio range.

A limitation of this type of range is the identity of the "A" or "N" signals in opposite quadrants. As shown in Fig. 1, the same signal is received in quadrant 1 as in quadrant 3 (also quadrants 2 and 4). Information as to the airplane position with respect to the radio-range station is thus *not* conveyed to the pilot—a potentially serious cause of difficulty in case a pilot is lost and desires to fly to the nearest airport with a minimum of fuel consumption. The reader is referred to the indicated reference for further information on visual indication for orientation under instrument flight.[1]

2. Two-Course Localizer

With this localizer, the type installed at Indianapolis, Indiana, some five years ago and now commonly used for instrument landing, two characteristic patterns are radiated *simultaneously* rather than successively. One pattern is modulated at 90 cycles and the other at 150 cycles. The course is determined by an indicating instrument of the zero-center type actuated by the ratio of the 90- and 150-cycle modulations. When this ratio is unity the pointer position is in the zero-center of the instrument scale, thus informing the pilot that he is "on course." Predominance of 90- or 150-cycle modulation causes the pointer to swing to the right or left, respectively, indicating "off-course" flight.

Despite the practicability of establishing a course at least three times more sharply defined than with the four-course range, the difficulty of locating position with respect to the radio-range station remains. This will be

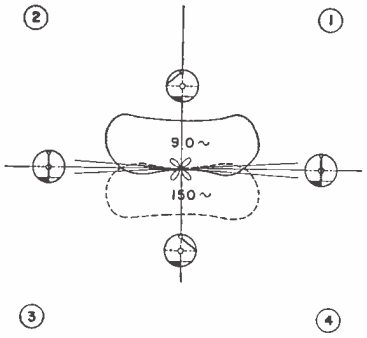


Fig. 2—Two-course localizer.

evident from Fig. 2; the same signal is received regardless of whether the airplane is in position "1" or "2" ("3" or "4"). The problem thus presented for solution was the identification of the sector at any instant so as to acquaint the pilot not only with his position with respect to the course (information which both the four-course radio range and the two-course localizer provide) but also his location with respect to the radio-range station.

Essential Range Requirements

Fig. 3 shows schematically the basic requirements and might represent any radio range, such as that at Indianapolis. Two indications are necessary: (1) deviation from

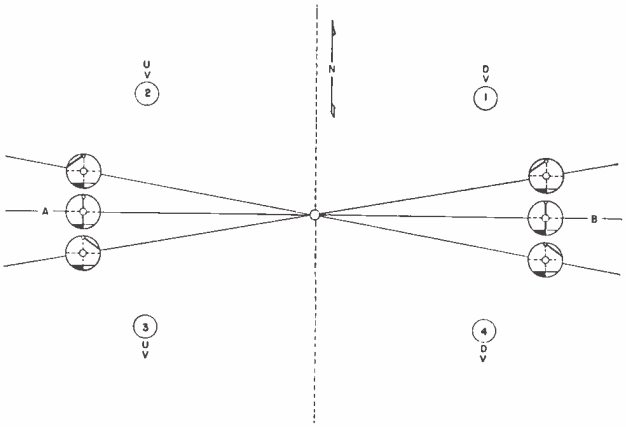


Fig. 3—Two-course radio range with sector identification and simultaneous voice.

the established course, provided visually by a zero-center type indicator which goes off scale approximately 10 degrees each side of the course; (2) aural sector identification; i.e., indication of the airplane position east or west of the radio-range station. In Fig. 3, the letter *V* represents voice which is radiated equally in all directions about the station.

[1] P. H. Redpath and J. M. Coburn, "Air Transport Navigation" Pitman Publishing Corporation, New York, N. Y., 1943, chapter 21, pp. 472–482.

Method of Solution

The solution of the signal problem of the two-course range with sector identification and simultaneous voice is indicated in Fig. 4. It is apparent from the preceding discussion that the two-course localizer provides a partial answer. Hence, two overlapping radiation patterns,

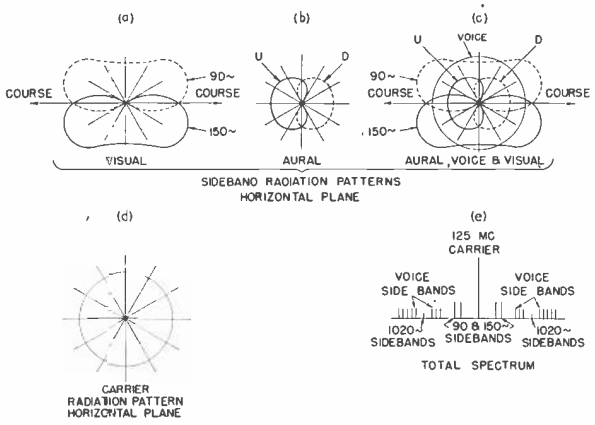


Fig. 4—Components of complete radiation.

modulated at 90 and 150 cycles, respectively, are transmitted simultaneously for the establishment of the east-west visual course (Fig. 4(a)). In addition, for aural sector identification, two radiation patterns are transmitted in immediate succession with interlocking D(— · ·) and U(· · —) characters; the first predominantly towards the east, and the second predominantly towards the west as in Fig. 4(b). Simultaneous voice, when applied, is radiated in a substantially circular pattern as illustrated in Fig. 4(c).

The complete radiation, aural, visual, and voice, is shown in Fig. 4(c), the relative sizes showing approximately the relative amplitudes of the aural, visual, and voice signals. The discussion concerning radiation patterns thus far refers to the sidebands only. By a process to be discussed shortly, the carrier which is common to the aural, visual, and voice signals is radiated in all directions as in Fig. 4(d). Under these conditions, Fig. 4(e) represents the total useful spectrum of the complete radio range.

Antenna Problem

The visual course radiations are produced by a group of three ultra-high-frequency loop antennas. These three antennas lie on a straight line perpendicular to the visual course with equal spacings between adjacent loops. The aural course radiators constitute a similar array oriented 90 degrees with respect to the visual group, the center loop being common to both groups. Voice, visual, and aural sidebands and carrier are radiated circularly only by the common center loop. The loop antennas used are the type previously described.[2]

[2] A. Alford and A. Kandoian, "Ultra-high frequency loop antennae," *Trans. A.I.E.E.*, (*Elec. Eng.*, 1940) vol. 59, pp. 843–848; 1940; and *Elec. Comm.*, vol. 18, pp. 255–265; April, 1940.

The antenna-array problem is illustrated schematically in Fig. 5. $S°$ represents the spacing of the loops in electrical degrees. With the amplitudes and spacings indicated the total radiation $F(\theta)$ in the horizontal plane is given by

$$F(\theta) = A \pm 2B \sin (S° \sin \theta). \quad (1)$$

The choice of sign depends upon the relative phase of the outer loops with respect to the center loop and de-

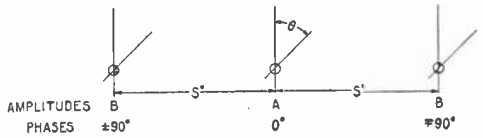


Fig. 5—Derivation of three-loop radio range.
$S°$ = spacing between loops in electrical degrees
Radiation pattern—horizontal plane: $F(\theta) = A \pm 2B \sin (S° \sin \theta)$
Visual antenna array: $A = 1$; $B = 0.707$; $S° = 135$ degrees
Aural antenna array: $A = 1$; $B = 0.5$; $S° = 100$ degrees

termines the particular image pattern obtained; the intersection of the two mirror-image patterns along direction $\theta = 0$ degrees and 180 degrees determines the

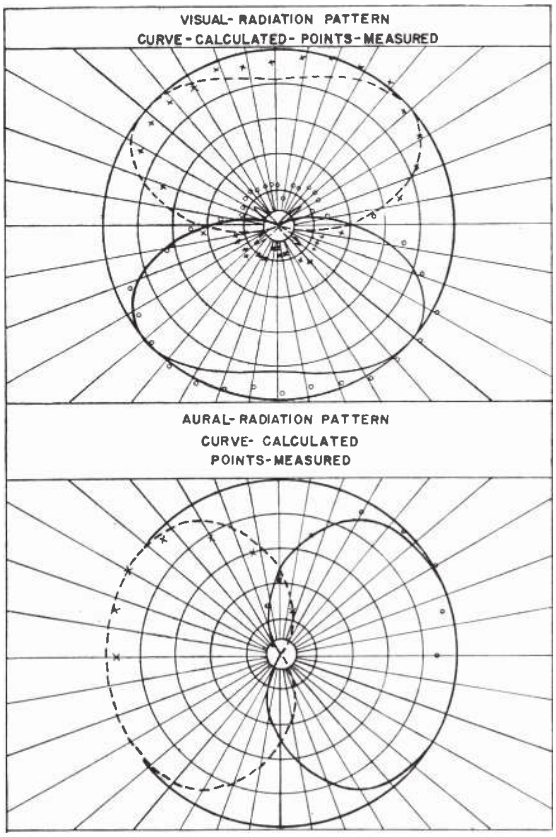


Fig. 6—Comparison of visual- and aural-radiation patterns.

established course. The first term A represents the radiation from the center loop; the second term, the radiation from the outer loops.

Equation (1) is generally applicable to overlapping radiation patterns. In this form, or slightly modified and

expanded, it may be applied to a variety of radio-range and localizer antenna arrays.

For the case of the visual and aural arrays, the requirements impose a division of power between the center and outer loops of $A=1$ and $B=\frac{1}{2}$ with $S=120$ degrees. These values give an infinite clearance at angles of ± 48.6 degrees to either course, where clearance is defined as the ratio of the field strength of one mirror-image pattern to the other at any selected distance from the station.

Fig. 6 shows the visual- and aural-sideband radiation diagrams for the values of A and B indicated in Fig. 5. This choice of current ratios and spacings is not the one used in the final range installation, but has been included to illustrate the effect of antenna spacings and current ratios on the radiation patterns.

1. Aural Array

The circuit of the aural antenna system is illustrated in Fig. 7. By keying at the indicated location, the phase of the two outer loops is reversed with respect to the phase of the center loop; hence, the desired mirror-image patterns are obtained alternately. In one radio-frequency keyer position, radiation occurs predominantly

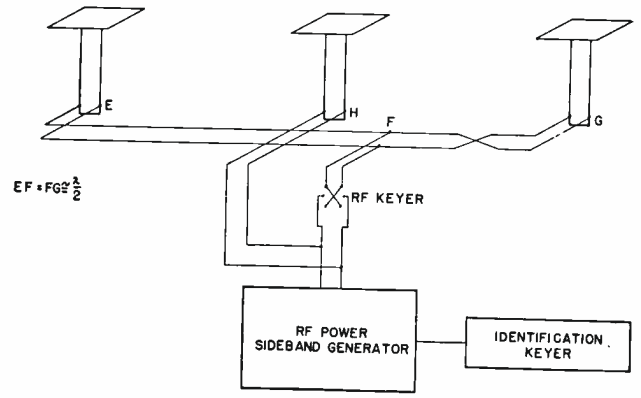


Fig. 7—Aural antenna network.

toward the east and the keyed identification is D. In the opposite position, radiation occurs predominantly towards the west and the keyed identification is U. Two separate antenna systems for radiating the two characteristic patterns consequently are avoided, inasmuch as the separate patterns are obtained at will by a simple phase reversal.

In this type of array, the problem of interaction between the various radiators must be considered. Since the outer loops have equal currents of opposite phase they do not induce any current in the center loop. The center loop, however, may excite the outer loops parasitically. This parasitic action can be controlled and made useful for certain applications. In the present case, however, it is undesirable and hence the relationship $EF=FG\cong\lambda/2$ is maintained (Fig. 7). This places a virtual short circuit at terminals E and G for parasitic currents, and detunes these loops insofar as parasitic action is concerned.

2. Visual Array

Fig. 8 depicts the visual antenna system which is similar to the aural array except that its position is oriented 90 degrees from the visual position. In this case, however, the two characteristic patterns must be transmitted simultaneously, rather than successively, so that a special network is required.

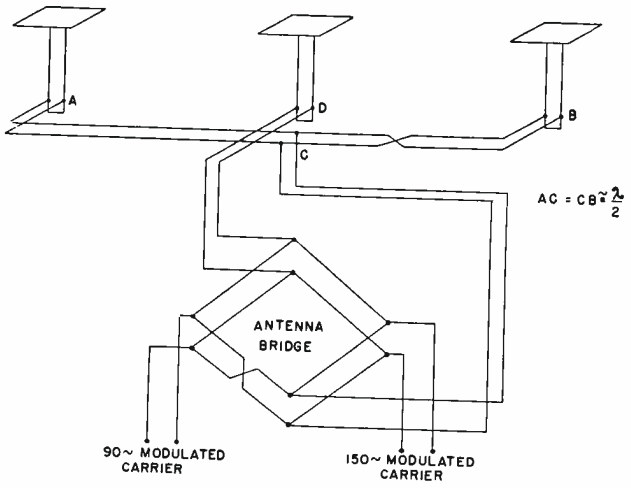


Fig. 8—Antenna network, two-course visual radio range.

This network, a transmission-line bridge, is indicated diagrammatically in Fig. 8. The 90- and 150-cycle modulations are fed into opposite terminals of the network and arrive at the center loop in phase; but because of the phase reversal in the arm of the bridge, they reach the outer loops in opposite phase. This results in the simultaneous mirror-image patterns, one with 90-cycle and the other with 150-cycle modulation.

The bridge circuit possesses another important advantage. At each of its two input terminals, in addition to the 90-cycle and 150-cycle sidebands, there is present the 125-megacycle carrier, which arrives at the respective input terminals of the bridge in phase. At the terminals leading to the outer loops, however, the carriers cancel out because of the previously mentioned phase reversal in one arm of the bridge. Contrariwise, at the center-loop terminals, the carrier is in phase and is therefore additive. Hence, no mirror-image patterns exist insofar as the carrier is concerned; the carrier is radiated only from the center loop equally in all directions. The sideband power, however, divides equally between the center and the outer antennas and makes possible the radiation patterns already described.

The transmission-line bridge thus serves three highly important functions: (a) the realization of two different radiation patterns from a single antenna array; (b) the removal of the sidebands from the carrier of two modulated waves of the same carrier frequency without any power dissipation; and (c) the radiation of the total carrier energy solely from the center loop with uniform circular distribution.

The Visual Modulation Problem

The problem of obtaining two equal sources of radio-frequency power modulated at 90 and 150 cycles, respectively, requires careful consideration. Early in the development of radio ranges it became evident that two separate transmitter output stages, each with its own modulation, was not satisfactory. This was due to the fact that variation of one output stage with respect to the other resulting from a change in tube emission, or any other reason, would alter the established course correspondingly. It was necessary, therefore, to divide the transmitter carrier output into two equal parts and modulate each half separately by means not subject to difficulties arising from change of tube emission. Mechanical modulation, consequently, was adopted.

The schematic diagram of the mechanical modulator is shown in Fig. 9. It will be seen that the transmitter

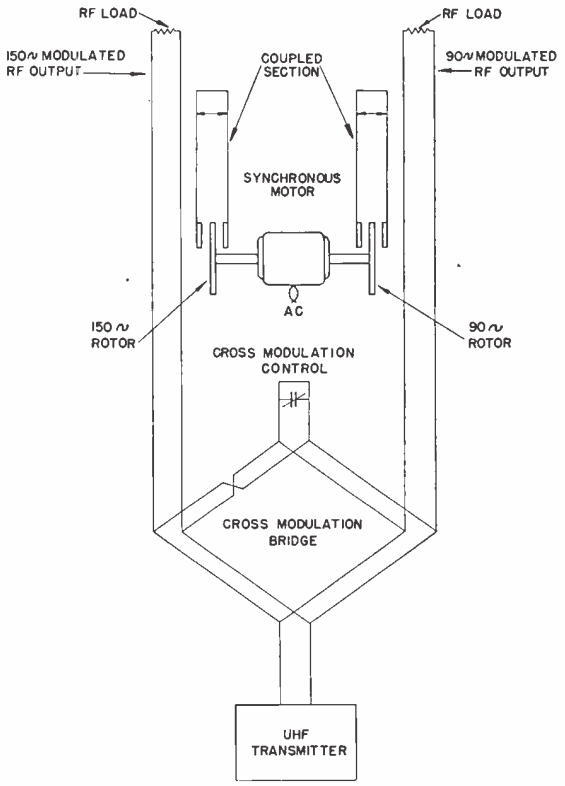
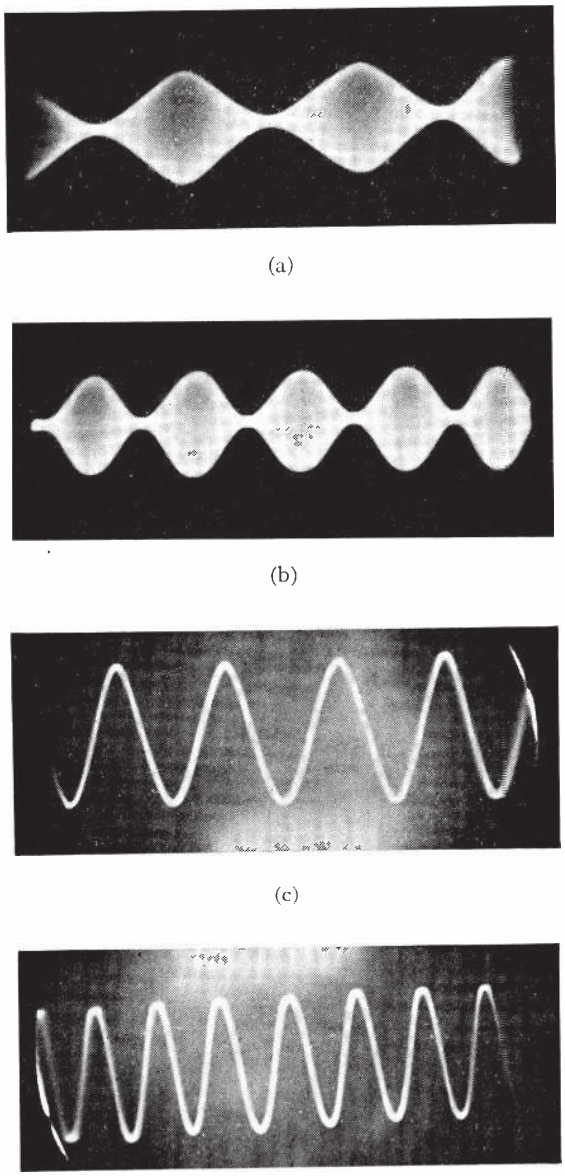


Fig. 9—Ultra-high-frequency mechanical modulator.

output is divided into two channels with a resonant quarter-wave section coupled to each. Under these conditions, the coupled sections effectively short-circuit the transmission line to the antennas.[3] These resonant sections are detuned periodically by 3- and 5-blade paddle wheels rotating at 1800 revolutions per minute. Thus the resulting output of each channel is modulated 100 per cent. By tuning the sections so that resonance is approached but not reached, any lesser degree of modulation may be obtained.

[3] Andrew Alford, "Coupled networks in radio-frequency circuits," Proc. I.R.E., vol. 29, pp. 55–70; February, 1941.

In arbitrarily dividing the output of a transmitter into two channels, special precautions are required to prevent cross modulation when the impedance of a channel varies during the modulation cycle. For this purpose the transmission-line bridge again proves to be



(a)

(b)

(c)

(d)

Fig. 10—Wave form from mechanical modulator.
(a) 90-cycle modulation radio-frequency envelope
(b) 150-cycle modulation radio-frequency envelope
(c) Detected 90 cycles
(d) Detected 150 cycles

a versatile tool. By varying the impedance at the terminal opposite the transmitting end, it is possible to make each branch entirely independent of the other, and hence obtain substantially zero cross modulation. It is, moreover, not difficult to show experimentally that no power need be lost in the bridge terminating network to obtain negligible, less than 1 per cent, cross modulation between channels.

The tendency prevails to associate mechanical modulation with jagged, distorted, or at least square-wave modulation rich in harmonic content. In the present case, however, this type of wave configuration is decidedly not obtained, as will be evident from Fig. 10, showing representative results. It is, in fact, not difficult to limit the total distortion of each channel to less than 10 per cent and, with somewhat more care, to less than 5 per cent.

Aural and Voice Modulation

The present method for application of aural and voice modulation is a result of several years development and experimentation. Throughout these years of growth leading to the present radio range, several methods were employed to achieve this addition. It seems logical, therefore, to describe the three major methods in the order in which they occurred.

Method I

Initially, only aural modulation without voice was used to obtain sector identification. In the adaptations

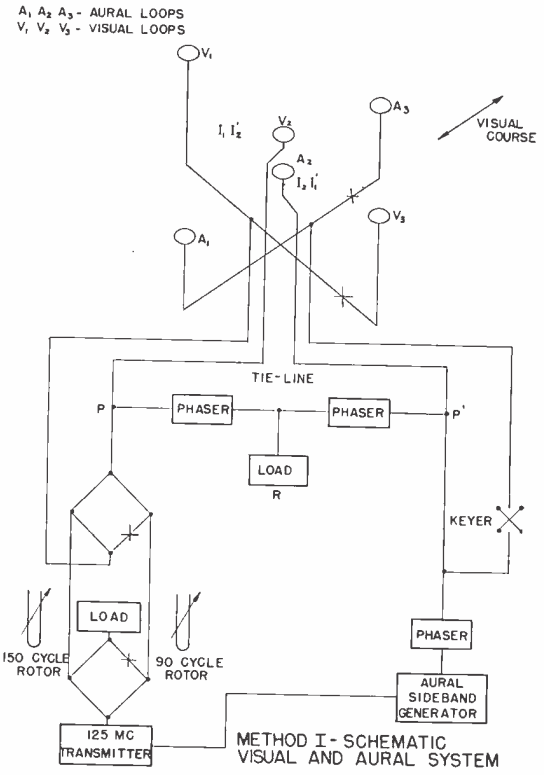


Fig. 11—Method I, schematic visual and aural system.
A_1, A_2, A_3=aural loops
V_1, V_2, V_3=visual loops

to be described later, voice is added to the total radiated spectrum.

It is evident if a separate carrier were used for the aural portion of the radio range, and the radiation directed by means of the radio-frequency relay first to the east, then to the west, the total carrier available at the receiver would fluctuate, and hence the automatic volume control of the receiver would be affected. This would cause "kicking" on the visual course-indicating instrument each time the aural signal was keyed. It follows, therefore, that some means must be provided to transmit only 1020-cycle sidebands for the aural signal and to make use of the already existing circularly radiated carrier from the visual-instrument course.

To accomplish these results, the aural-channel facilities employ a sideband generator giving an output predominance of sideband to carrier of 30 to 40 decibels depending upon the care exercised in adjustment. At the output of the sideband generator, a phaser is provided to obtain the correct phase relationship between the sidebands thus produced and the carrier from the main transmitter.

Since a carrier common to both the aural and visual modulation is utilized, it is not desirable to modulate the carrier in the mechanical modulator 100 per cent.

This modulation, therefore, is reduced to approximately 70 per cent and the aural signal then modulates the remaining 30 per cent.

Interaction Problem

Method I

The block schematic diagram of method I of the two-course radio range with sector identification is shown in Fig. 11. The visual and aural loops shown in this illustration are positioned above a metallic counterpoise.

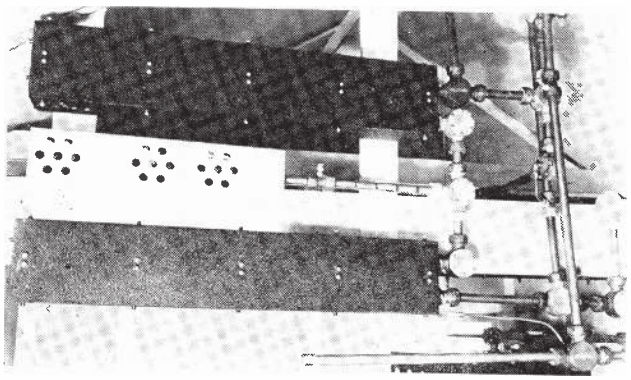


Fig. 12—Tie line used in method I to prevent interaction between aural and visual antenna systems.

The visual loops are placed a half wave above the counterpoise and the aural loops slightly more than one quarter. From previous discussion it is clear that the four outer loops induce no currents in the center loops. The center two loops, on the other hand, do not induce currents in the outer loops because these loops are detuned for parasitic current, since in Figs. 7 and 8

$$AC = CB = EF = FG \cong 180 \text{ degrees.}$$

Thus care is taken of all interaction, except that between the two center loops, one mounted above the other. The coupling between these two loops is serious because the visual signal will get into the radio-frequency relay in the aural circuit; furthermore, the aural sidebands would feed back into the mechanical modulator. Thus, a great deal of undesirable interaction

between the aural and visual systems would result.

These difficulties are overcome by means of a properly designed tie line such as the one shown in Fig. 11. The installed tie line is shown in Fig. 12. The general function of the line is to borrow power from the source, and control it in phase and amplitude so as to neutralize the unwanted voltage at a specific point.

The design considerations will be clear from the following: assume the directly fed current in the visual center loop V_2 (Fig. 11) is represented by I_1 and the induced current in the center aural loop A_2 is I_1'. If, now, a short circuit is applied along the feeder to the lower loop, it is evident that I_1' can be controlled in amplitude and to a certain extent in phase. In fact I_1' can be made negligibly small by placing the short circuit at the correct location P'. In practice, instead of an actual short circuit, a virtual short circuit is produced by means of the tie line. As a result, the top center loop is made substantially independent of the lower center loop. Conversely, point P can be located on the visual center-loop feeder in a manner such as to neutralize all the current induced in the top loop by the lower loop. The tie line, to be effective, requires a minimum of two controls: one for change of phase and another for amplitude. For phase control, some resistance is necessary in the circuit. Optimum design dictates very low power dissipation; but with negligible power loss, tuning of the line becomes critical. A power dissipation of approximately 10 per cent in the resistance load T (Fig. 11) results in adjustments that are readily made and stay put indefinitely.

Method I had the following disadvantages which resulted in its replacement by method II: (1) the tie line employed for the prevention of interaction between the center loops did not lend itself to adjustment by a maintenance man; and (2) the lower height of the outside aural loops above the metallic counterpoise gave rise to a radiated vertical component along the visual course. This vertical component occurred due to reradiation from a high current concentration induced in the metallic counterpoise below the center aural loop by the outside aural loops. In such an ultra-high-frequency radio range utilizing horizontal polarization, freedom from any vertical polarization is highly essential if the course is to be independent of the attitude of the airplane. If the course is dependent on the attitude of the airplane, a flight phenomenon known as "pushing" occurs, and the plane will zig-zag about the course in attempting to follow it.

Method II

A block schematic of the second method appears in Fig. 13. This differs from the previous method by the addition of voice to the system and the elimination of one center loop antenna and associated tie line.

The use of a bridge permits one antenna to be energized by two different sources without interaction between them. This ability of the bridge is utilized to excite a single center loop by both the visual and the combined aural and voice channels,[4] as illustrated in Fig. 13. The bridge B_1 also prevents either channel from feeding into the other.

Another bridge B_2 is used to apply voice. The voice facilities consist of an additional sideband generator and modulator. A phaser is provided at the output of each sideband generator to place the sidebands in the proper phase relation with the carrier at the output of bridge B_1 feeding the center antenna.

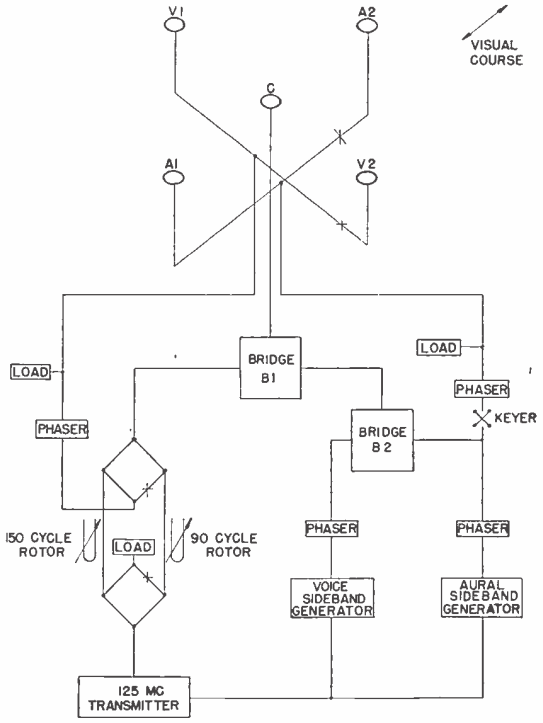


Fig. 13—Method II, schematic visual, voice, and aural system.
A_1, A_2, C=aural loops
V_1, V_2, C=visual loops
C=voice loop

The voice sidebands do not feed into the aural outside antennas, due to the action of the bridge B_2. Likewise, the aural sidebands cannot reach the output of the voice generator.

Initially, the voice sideband generator was modulated by a 20-kilocycle subcarrier. This 20-kilocycle subcarrier was modulated with voice. The voice facilities were later provided with a switching arrangement to permit an instantaneous change from voice on the subcarrier to voice directly on the main carrier. This permitted a close comparison during actual flight tests. With voice directly on the main carrier, a 1020-cycle rejection and a high-pass filter were provided in the voice channel to prevent any disturbance in the visual and aural courses with voice modulation. Flight checks showed equivalent results between the two methods of voice modulation.

The loads on the outside antenna feed lines shown in Fig. 13 are used to dissipate an amount of sideband

[4] The use of the transmission-line bridge in this manner was first suggested by W. E. Jackson, chief of the Radio Development Section of the Civil Aeronautics Administration.

energy necessary to give the proper power ratio in the outside loops to the center loop.

Method II had one inherent disadvantage. Half of the total carrier power was dissipated in the load terminating the bridge B_1. As a consequence, method II was replaced by method III.

Method III

The final system used utilizes an adaptation of the mechanical-modulator bridge arrangement to the aural and voice channels. The sideband generators used in the previous method have been replaced by two 35-watt radio-frequency amplifiers (No. 1 and No. 2), shown in Fig. 14. Amplifier No. 1 is modulated with voice plus

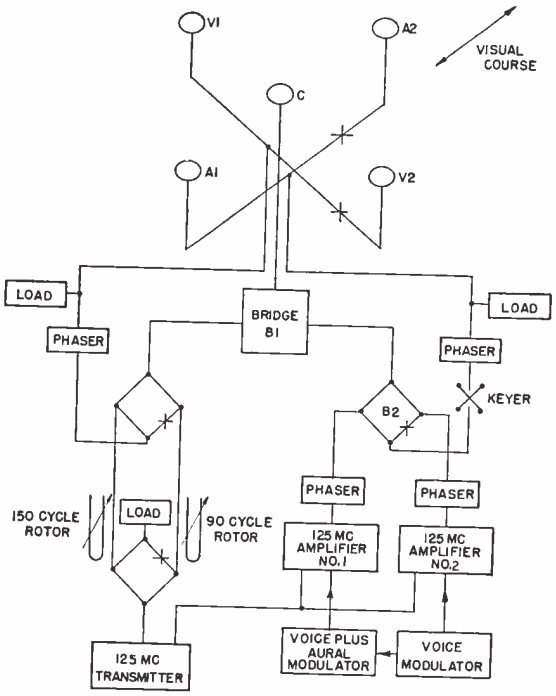


Fig. 14—Method III, schematic visual, aural, and voice system.
V1, V2, C=visual loops
A1, A2, C=aural loops
C=voice loop

1020 cycles, while amplifier No. 2 is modulated with voice only. The percentage of voice modulation on the equal carrier outputs of each radio-frequency amplifier is the same. As a result, the voice sidebands and carriers cancel out at the terminals of bridge B_2 feeding the outside aural antennas. The 1020-cycle sidebands of amplifier No. 1 divide equally between the center- and aural-antenna feed lines.

Since no crossover exists in the arms terminating in the upper junction of bridge B_2, the carriers and voice sidebands of both amplifiers add. The carrier power dissipation at bridge B_1 is now a small fraction of that dissipated in Method II. The sideband generators, which require careful adjustment, have been replaced by straightforward radio-frequency amplifiers.

The percentage modulation of each channel on the carrier is approximately 50 per cent for the visual, 35 per cent for the voice, and 15 per cent for the aural sidebands. These values were found optimum by actual flight tests.

125.020-Megacycle Marker

A problem which presented itself, when flight checks were begun on this radio range, was irregularity of pointer indication when the plane flew at high vertical angles with respect to the transmitting equipment. This was due to lack of directly radiated signals, since the loop antennas have substantially zero radiation vertically. The receiver in the plane, because of its automatic-volume-control characteristic, became very sensitive and picked up whatever stray signal existed and hence gave irregular pointer indication.

Several possible solutions were discussed with the Civil Aeronautics Administration personnel, and as a result, a special marker was used to overcome this difficulty. Fig. 15 shows the marker array which is fed from

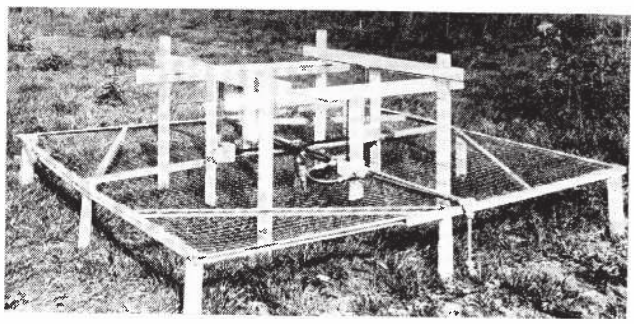


Fig. 15—125.020-megacycle marker antenna array.

an auxiliary 30-watt transmitter removed in frequency from the main transmitter by approximately 20 kilocycles. This signal has no modulation and serves merely to radiate carrier straight up in order to steady the cross-pointer indicator and silence the receiver in the airplane at high vertical angles over the radio-range station.

Equipment

The receiver, designed for this radio range, is a Western Electric type RUM crystal-controlled 125-megacycle superheterodyne with an intermediate frequency of 10 megacycles. A high-pass filter, above 150 cycles with 1020-cycle rejection, in conjunction with a 90- and 150-cycle pass filter and a 1020-cycle pass filter, were inserted in the audio channel to separate the aural and voice signals from the 90- and 150-cycle visual signals. A more recent receiver, the Western Electric type 32A, has also been used in flight checks with very satisfactory results. The course indication is provided by a Weston cross-pointer instrument, the vertical pointer of which is utilized as illustrated in Fig. 2. The cross-pointer instrument is used in conjunction with 90- and 150-cycle pass filters in parallel. The outputs of the filters are rectified to actuate the meter. With a predominance of 90-cycle modulation, the vertical pointer deflects to the right of its "on course" or center position, while a predominance

of 150-cycle modulation swings the pointer to the left. The receiving loop antenna on the airplane is similar to the type used for instrument landing.[5]

Figs. 16, 17, 18, 19, and 20 show views of the complete radio range, the transmitting equipment, antennas, and the airplane equipment comprised in the radio range.

Fig. 16—Two-course radio range with sector identification and simultaneous voice, showing transmitter house, counterpoise structure, antenna house, and 125.020-megacycle marker.

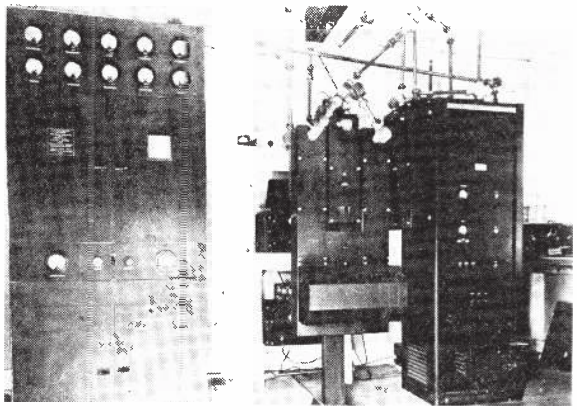


Fig. 17—Transmitting equipment, showing left to right, 125-megacycle, 300-watt transmitter, mechanical modulator, and sideband generator. Auxiliary marker transmitter is in the background.

Acknowledgment

The help and co-operation of the Radio Development Section of the Civil Aeronautics Administration and particularly the personnel of the Civil Aeronautics Administration Experimental Station of Indianapolis, Indiana, is gratefully acknowledged.

[5] P. C. Sandretto, "Principles of Aeronautical Radio Engineering," McGraw-Hill Book Company, Inc., New York, N. Y., 1942, chapter III, pp. 100–105.

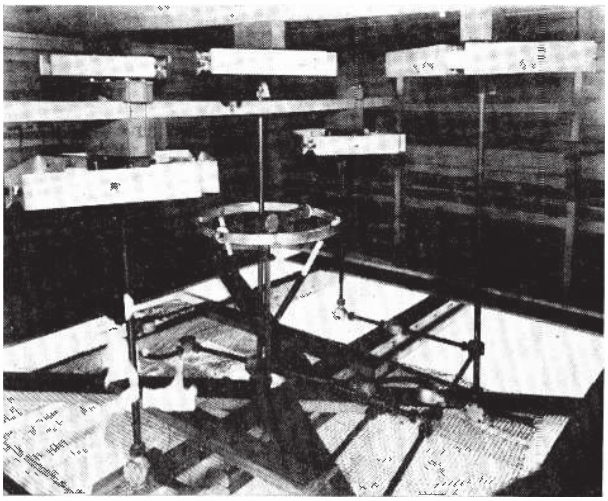


Fig. 18—Visual and aural loop antennas mounted above metal counterpoise.

Fig. 19—Civil Aeronautics Administration Boeing used in flight checks, showing receiving loop antenna.

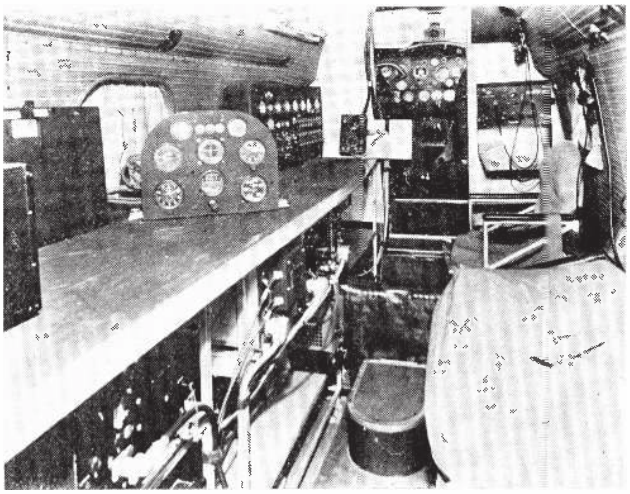


Fig. 20—Cabin view of Civil Aeronautics Administration Boeing ready for demonstration flights.

A Simple Optical Method for the Synthesis and Evaluation of Television Images*

ROBERT E. GRAHAM†, MEMBER, I.R.E. AND F. W. REYNOLDS†

Summary—**A combination of a 35-millimeter motion-picture projector and a line screen enables the projection of still or motion pictures closely similar in appearance to those produced by television. This similarity of appearance is checked theoretically by an analysis of the type previously reported by Mertz and Gray in a discussion of the theory of scanning. From the analysis it is shown that five parameters of the optical-simulation system may be varied to obtain the equivalent of variations in television factors such as number of scanning lines, size and configuration of scanning apertures, and width of frequency band.**

Photographs of simulated television pictures projected by this method are presented. These pictures include subject matter of general interest as well as selected subjects to illustrate the spurious detail components introduced by the television scanning process. These components produce moiré patterns, "steps" on diagonal lines, and impairment of vertical resolution. Simulation pictures projected by this method have been compared with those produced by a television system and the expected agreement observed.

Calculations are given of the diffraction effects in optical systems of this type and it is shown that the departure from geometrical theory is small in the arrangements described.

I. Introduction

IMAGE transmission systems are often compared in terms of frequency bandwidth, number of scanning lines, and picture repetition rate. Specification of these factors sets a theoretical upper limit for the system performance. However, a number of other variables exist which may greatly influence the image quality. Among these are picture brightness, over-all tone reproduction, and the admittance characteristics of the scanning apertures. It is possible to measure these quantities, but difficult to obtain a quantitative estimate of their effects upon subjective image quality. It is therefore desirable to make subjective studies of such factors, employing real or simulated television systems.

Optical-simulation methods have been found useful in conducting these studies and in providing reproducible standards of image quality. Several methods have been suggested and used for these purposes. Engstrom[1] has described a method of optical simulation which uses crossed pieces of lenticular film for subdividing an image into elemental areas or picture elements. Goldmark and Dyer[2] have described a mechanical scanning arrangement which produces television-simulation photographs. Baldwin[3] has used a motion-picture projector for simulating television images for direct viewing, the area of confusion being determined by the amount of defocusing and an adjustable aperture at the projection lens.

The method of simulation described in this paper employs an out-of-focus optical system in combination with a suitable line screen. Use of the latter enables an accurate reproduction of the spurious components which result from the strip-scanning process employed in television. It is well known that these components cause a definite loss in vertical resolution as well as occasional annoying patterns which are superposed upon the normal image. They appear as a step-like structure at oblique edges of object detail, and as moiré patterns when an array of object lines forms a small angle with the scanning direction. In previous simulation work[3] the effects of the spurious components upon picture sharpness have been evaluated and allowed for on the basis of subjective comparisons between out-of-focus simulation images and television images of known characteristics.

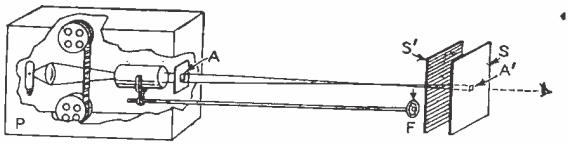


Fig. 1—Optical-simulation apparatus.

The theory underlying the line-screen method of simulation is developed at some length in this paper, and it is shown that the method is capable of accurately simulating the television process. Several examples of simulation are shown and discussed, including subject matter particularly selected to exhibit pronounced spurious patterns.

II. Description of Apparatus

A pictorial sketch of the equipment used in the simulating process is shown in Fig. 1. A 35-millimeter motion-picture projector P projects images from ordinary film on the ground-glass screen S. A line screen S' consisting of a parallel array of alternate lines and spaces is interposed between the projector and the screen S. The projected image is focused a given distance on the near side of S' by means of the focusing control F, which

* Decimal classification: R583. Original manuscript received by the Institute, June 18, 1945. Presented, Sixteenth Annual Convention, New York, N. Y., January 11, 1941.

† Bell Telephone Laboratories, New York, N. Y.

[1] E. W. Engstrom, "A study of television image characteristics," Proc. I.R.E., vol. 21, pp. 1631–1652; December, 1933.

[2] P. C. Goldmark and J. N. Dyer, "Quality in television pictures," *Jour. Soc. Mot. Pic. Eng.*, vol. 35, pp. 234–253; September, 1940.

[3] M. W. Baldwin, Jr., "The subjective sharpness of simulated television images," *Bell. Sys. Tech. Jour.*, vol. 19, pp. 563–587; October, 1940.

controls the position of the projector lens. This results in an out-of-focus image on S, each subject point giving rise to a uniform[4] area of light A', which is a shape replica of the projector aperture A.

The control elements of the apparatus are: (1) the degree of out-of-focus of the projected image; (2) the number of lines in the screen S'; (3) the configuration of the aperture A; (4) the positioning of the line screen between the projector and S; and (5) the nature of the opacity variation found by traversing the alternate lines and spaces of S'. These factors collectively determine the simulated television picture.

Briefly, the significance of these five factors is as follows: (1) determines the general resolution level of the picture; (2) fixes the number of scanning lines in the equivalent television system; (3) determines the configuration of the television scanning apertures; (4) provides an adjustment for controlling the nature of the spurious components; and (5) determines the amplitude of the spurious components.

The pictures appearing in this paper were, except as noted, taken under the following conditions. The projector lens had a focal length of 6 inches and was used with a square aperture approximately 0.7 inch on a side. The projected image was 8 by 10 inches and was formed at an image distance of about 6 feet. The line screen contained approximately 400 black lines across the 8-inch dimension.

In projecting still pictures with the apparatus, it was found desirable to insert a water cell between the film gate and the light source to avoid excessive heating of the film. Also, film buckling was minimized by mounting the film between glass slide covers. In order to obtain a uniform light distribution across the projector aperture A, a ground-glass diffusing screen was inserted behind the film gate. For direct comparison of the simulation pictures with actual television pictures, a color match was desirable. This was attained by placing appropriate color filters behind the film gate.

III. Theory of Optical Simulation

The manner in which the optical system of Fig. 1 makes possible an accurate television simulation may be brought out by developing a mathematical expression for the transformation of the initial picture field into the final image field as seen at S. This expression will be compared with a like expression for the transformation of the subject picture produced by television systems. The similarity of result obtained in the two cases will be used to support the validity of the simulation method.

A diagrammatic sketch of the optical system is shown in Fig. 2. On the basis of geometrical theory, the light from the point of the film plane on the optical axis passes through the lens, is restricted to a ray bundle bounded by the aperture A, converges to a point on the axis at the sharp-focus plane S'', and then diverges to a light spot A' on the screen S. The "confusion area" A' has the same boundary shape as the aperture A, but does not contain a uniform distribution of light because of the striation introduced by the line screen S'. Similarly off-axis points in the film plane are refocused in the plane S'' and give rise to confusion areas at S similar in shape to the aperture A.

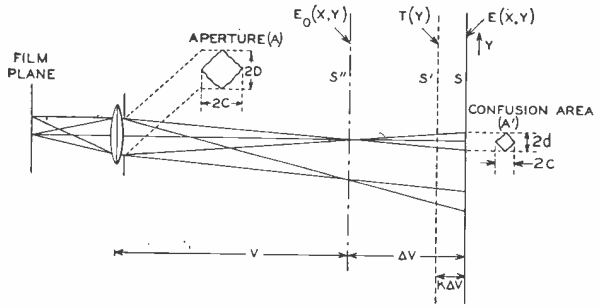


Fig. 2—Diagrammatic arrangement of optical-simulation system.

Setting up a system of axes with the y axis vertical, the x axis perpendicular to the plane of the drawing, and the origin on the optical axis; the intensity of illumination falling on the S'' plane may be written as $E_0(x, y)$. This function represents the effective brightness distribution in the subject picture, and thus may be treated as the source picture field. The illumination intensity at S may be written as $E(x, y)$, this function representing the simulation picture field. Since the lines of the screen S' are oriented parallel to the x axis and are presumed to be uniform in opacity, the optical transmission of the screen may be written as a function of y alone, $T(y)$.

For a convenient though unnecessary approximation, it will be assumed that the increase in image magnification in going from S'' to S may be neglected. This approximation is valid as long as

$$\frac{\Delta v}{v} \ll 1,$$

a condition which will be fulfilled readily in the usual case.

Out-of-Focus Transformation Without Line Screen

Before evaluating $E(x, y)$ in terms of $E_0(x, y)$ for the actual system, the simple out-of-focus transformation omitting the screen S' will be treated.

Referring to Fig. 3, any point x, y in the sharp-focus plane S'' gives rise to a uniformly illuminated confusion area, A' on S. The boundary of the divergent cone of light from x, y is indicated by the solid lines. If the boundary of A' is symmetrical about an origin taken at x, y then it may be seen that the point x, y on S receives light from that portion of S'' which is identical

[4] Actually the light distribution in A' is uniform only in the absence of the line screen S'.

in shape, size, and orientation with A'. The envelope cone of the rays from S'' reaching x, y of S is indicated by the dotted lines.

Thus a measure of the resultant illumination intensity at a point x, y of S may be determined by summing up the contributions from S'' over a region A' of S'' centered at x, y. Since the contributions of points on S'' are weighted according to the function $E_0(x, y)$, the illumination $E(x, y)$ falling on S may be expressed as follows (neglecting constant factors):

$$E(x, y) = \int\int_{A'} E_0(x + \xi, y + \eta)d\xi d\eta, \qquad (1)$$

where ξ and η are integration variables measured on an auxiliary set of axes centered[5] at x, y.

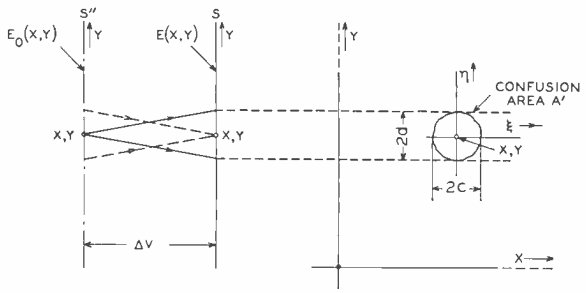


Fig. 3—Analysis of out-of-focus image transformation, without line screen.

In order to interpret (1), it is necessary to adopt some functional representation for $E_0(x, y)$. The form chosen here is the two-dimensional Fourier series used by Mertz and Gray.[6] The light distribution in the plane S'' is set up as an image field as indicated in Fig. 4. The origin of axes is taken at the center of the field as previously described, and the field height and width are $2b$ and $2a$ respectively. Then the intensity of illumination, $E_0(x, y)$, may be represented at any point of the field S'' by the expression

$$E_0(x, y) = \sum_{m=0}^{\infty} \sum_{n=-\infty}^{\infty} a_{mn} \cos\left[\pi\left(\frac{mx}{a} + \frac{ny}{b}\right) + \phi_{mn}\right], \qquad (2)$$

where any component m, n of the summation represents a sinusoidal variation of illumination intensity extending across the image field. The wavelength of the intensity variation is given by

$$\lambda_{mn} = \frac{1}{\sqrt{\frac{m^2}{4a^2} + \frac{n^2}{4b^2}}},$$

while the orientation of the wave front is given by

$$\tan\theta = \frac{-mb}{na},$$

θ being the angle formed with the x axis.

For mathematical simplicity, (2) may be written in exponential form as follows:

$$E_0(x, y) = \sum_{m=-\infty}^{\infty} \sum_{n=-\infty}^{\infty} A_{mn} e^{i\pi(mx/a + ny/b)}, \qquad (3)$$

where

$$A_{mn} = \frac{a_{mn}}{2} e^{i\phi_{mn}}$$

and

$$A_{-m,-n} = \frac{a_{mn}}{2} e^{-i\phi_{mn}}.$$

Substituting (3) in (1), there results

$$E(x, y) = \sum_{m=-\infty}^{\infty} \sum_{n=-\infty}^{\infty} Y(m, n) A_{mn} e^{i\pi(mx/a + ny/b)}, \qquad (4)$$

where

$$Y(m, n) = \int\int_{A'} e^{i\pi(m\xi/a + n\eta/b)} d\xi d\eta. \qquad (5)$$

Thus the result of the simple out-of-focus transformation in the absence of the line screen is to multiply each component m, n by an amplitude or "admittance" factor

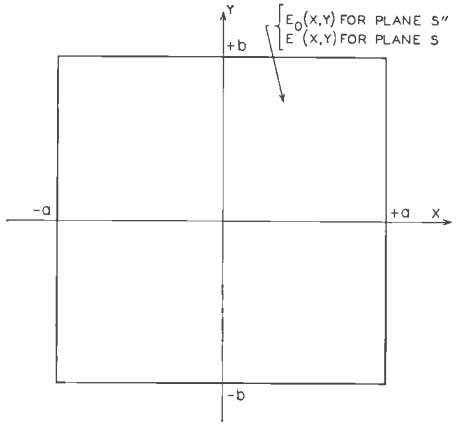


Fig. 4—Image field.

$Y(m, n)$. In general this admittance factor as given by (5) has a decreasing amplitude with decreasing component wavelength, thereby acting as a kind of low-pass filter. For example, if A' is taken to be a rectangle of height $2d$ and width $2c$, then (5) readily yields, neglecting constant factors,

$$Y(m, n) = \left(\frac{\sin\frac{\pi mc}{a}}{\frac{\pi mc}{a}}\right)\left(\frac{\sin\frac{\pi nd}{b}}{\frac{\pi nd}{b}}\right). \qquad (6)$$

[5] If a variable-density film is used as the projector aperture A, rather than a shaped hole, then an aperture transmission factor $T(\xi, \eta)$ must be introduced in the integrand of (1).

[6] P. Mertz and F. Gray, "A theory of scanning and its relation to the characteristics of the transmitted signal in telephotography and television," *Bell. Sys. Tech. Jour.*, vol. 13, pp. 464–515; July, 1934.

A plot of (6) for $m=0$, and $b/d=0.707N$ is given by curve A of Fig. 6. Only positive values of n are plotted, since $Y(0, n)=Y(0, -n)$.

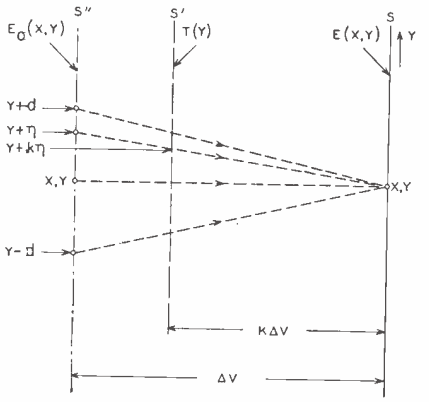


Fig. 5—Comparison of television and simulation systems.

Out-Of-Focus Transformation With Line Screen

Returning to the complete system, Fig. 2, including the line screen S', the manner in which points on S'' contribute to the illumination at the point x, y of S is indicated in Fig. 5. As before, the envelope of the cone of rays from S'' reaching x, y of S is indicated by the dotted lines drawn from the points marked $y+d$ and $y-d$, respectively. Letting $y+\eta$ represent the ordinate

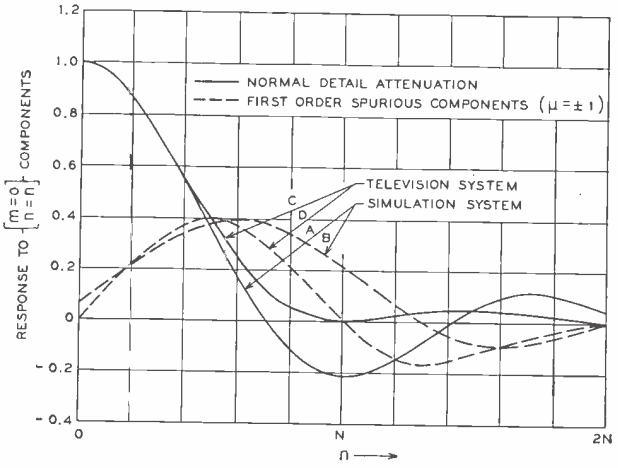


Fig. 6—Analysis of out-of-focus image transformation, with line screen.

of any point of S'' within this cone, it may be seen that the contribution of the point $x+\xi$, $y+\eta$ to the illumination intensity at x, y of S depends not only upon $E_0(x, y)$ as before, but also upon the transmission of the screen S' at the point where the ray from $x+\xi$, $y+\eta$ intersects it. The ordinate of this point of intersection is seen to be $y+k\eta$, where k is the ratio of the $S'S$ spacing to the $S''S$ spacing. Therefore, summing contributions over the region A',

$$E(x, y) = \iint_{A'} E_0(x+\xi, y+\eta)T(y+k\eta)d\xi d\eta, \quad (7)$$

where $T(y)$ is the transmission of the screen S'. If the height of the image field $2b$ is taken to contain exactly N black lines of the screen S', N being an integer; then the transmission characteristic $T(y)$ may be written as a single dimensional Fourier series of the form

$$T(y) = \sum_{\mu=-\infty}^{\infty} T_\mu e^{i\pi\mu N y/b}. \quad (8)$$

For simplicity the screen S' will be positioned symmetrically with respect to the x axis. Then the coefficients T_μ will be pure real quantities and

$$T_\mu = T_{-\mu}.$$

Substituting (3) and (8) into (7), there results

$$E(x, y) = \sum_{m=-\infty}^{\infty} \sum_{n=-\infty}^{\infty} \sum_{\mu=-\infty}^{\infty} Y(m, n+k\mu N) \cdot T_\mu A_{mn} e^{i\pi(mx/a+(n+\mu N)y/b)} \quad (9)$$

where $Y(m, n+k\mu N)$ is an admittance factor whose form is obtained by substituting $(n+k\mu N)$ for n in (5).

Equation (9) may be rewritten as follows, neglecting a constant factor:

$$E(x, y) = \sum_{m=-\infty}^{\infty} \sum_{n=-\infty}^{\infty} Y(m, n) A_{mn} e^{i\pi(mx/a+ny/b)} + \sum_{m=-\infty}^{\infty} \sum_{n=-\infty}^{\infty} \sum_{\mu=-\infty}^{\infty} Y(m, n+k\mu N) \cdot \left(\frac{T_\mu}{T_0}\right) A_{mn} e^{i\pi(mx/a+(n+\mu N)y/b)}, \ \mu \neq 0, \quad (10)$$

where T_0 is the value of T_μ for $\mu=0$.

The first term in the right member of (10) is identical with the expression given by (4) for the out-of-focus transformation in the absence of the line screen. This term may be called the "normal detail" field, since it contains only components which were present in the original subject matter, attenuated by the admittance factor $Y(m, n)$.

The second term of (10), contributed by the line screen, evidently may be classified as a "spurious detail" field, since the indexes of the components do not correspond to those of the original image.[7]

The significance of (10) may be brought out more clearly by the fact that a component m, n of the original image field, having an amplitude A_{mn}, gives rise in the simulation image, not only to an identical component m, n, having an amplitude $Y(m, n)A_{mn}$; but also to a

[7] However, it is possible for certain components of the spurious field to coincide in wavelength and orientation with normal-detail components.

set of spurious components m, $n+\mu N$, having amplitudes $Y(m, n+k\mu N)\ (T_\mu/T_0)\ A_{mn}$. Here μ is any positive or negative integer. If the series of $T(y)$ is rapidly convergent, as it will be if the lines and spaces of the screen are roughly equal in width, and if the transition from "line" to "space" is gradual rather than sharp,[8] then

$$\frac{T_\mu}{T_0} \ll 1, \quad \text{for} \quad |\mu| > 1.$$

Under these conditions, the higher order components may be neglected, and the spurious components derived from a subject component m, n may be written as $m, n \pm N$, having amplitudes $Y(m, n \pm kN)\ (T_1/T_0)\ A_{mn}$. These expressions will be found to be similar to those of the television system.

IV. Television-Image Analysis

A two-dimensional Fourier analysis of the picture degradation imposed by television systems has been widely published.[6] The results of this analysis may be summarized as follows.

Assuming negligible frequency-channel limitation, the television image may be expressed by

$$E(x, y) = \sum_{m=-\infty}^{\infty} \sum_{n=-\infty}^{\infty} \sum_{\mu=-\infty}^{\infty} Y_1(m, n) Y_2(m-\mu, n+\mu N) \cdot A_{mn} e^{i\pi[(m-\mu)x/a + (n+\mu N)y/b]} \tag{11}$$

where Y_1 and Y_2 are the admittance characteristics corresponding to the transmitting and the receiving scanning apertures (or beams) respectively, and N is the number of scanning lines. If the optical confusion area A' of (5) is replaced by the aperture area of the transmitter or receiver, then $Y_1(m, n)$ or $Y_2(m, n)$ may be found[9] from (5).

As in the case of (9), (11) may be written as the sum of a normal and a spurious field. Thus,

$$E(x, y) = \sum_{m=-\infty}^{\infty} \sum_{n=-\infty}^{\infty} Y_1(m, n) Y_2(m, n) A_{mn} e^{i\pi(mx/a + ny/b)} + \sum_{m=-\infty}^{\infty} \sum_{n=-\infty}^{\infty} \sum_{\mu=-\infty}^{\infty} Y_1(m, n) Y_2(m-\mu, n+\mu N) \cdot A_{mn} e^{i\pi[(m-\mu)x/a + (n+\mu N)y/b]}, \quad \mu \neq 0. \tag{12}$$

The first term of (12) is the normal field, being the same as the normal field of (10) if $Y(m, n)$ is replaced by $Y_1(m, n)$, $Y_2(m, n)$. The second term of (12) is the spurious field, there appearing to be somewhat more difference between this term and the spurious field of (10) than was found between the two normal fields. However, the difference is not important, as will be seen.

V. Comparison Between Simulation and Television Formulas

Normal-Field Comparison

Returning to the consideration of the normal fields, definite constants for the television and simulation systems will be chosen to achieve concreteness.

The television apertures will be taken as identical squares of side equal to the scanning-line pitch. The optical area of confusion A' will be taken as a square of side k_1 times that of either television aperture. Also the number of black lines in the line screen will be taken equal to the number of television scanning lines.

Under these conditions we may write, from (6), the normal-field admittance factor for the television system as[10]

$$Y_1(m, n) Y_2(m, n) = Y_1^2(m, n) = \left[\frac{\sin \frac{\pi m}{N}}{\frac{\pi m}{N}}\right]^2 \cdot \left[\frac{\sin \frac{\pi n}{N}}{\frac{\pi n}{N}}\right]^2 = Y_1^2(m, 0) \cdot Y_1^2(0, n), \tag{13}$$

and the corresponding quantity for the simulation system as,

$$Y(m, n) = Y_1(k_1 m, k_1 n) = \left[\frac{\sin \frac{\pi k_1 m}{N}}{\frac{\pi k_1 m}{N}}\right] \left[\frac{\sin \frac{\pi k_1 n}{N}}{\frac{\pi k_1 n}{N}}\right] = Y_1(k_1 m, 0) Y_1(0, k_1 n). \tag{14}$$

Expanding $Y_1^2(m, 0)$ in a Taylor's series,

$$Y_1^2(m, 0) = 1 - \frac{1}{3}\left(\frac{\pi m}{N}\right)^2 + \frac{2}{45}\left(\frac{\pi m}{N}\right)^4 - \cdots. \tag{15}$$

Similarly,

$$Y_1(k_1 m, 0) = 1 - \frac{k_1^2}{6}\left(\frac{\pi m}{N}\right)^2 + \frac{k_1^4}{120}\left(\frac{\pi m}{N}\right)^4 - \cdots. \tag{16}$$

Equating coefficients of $(\pi m/N)^2$ in (15) and (16), we find $k_1 = \sqrt{2}$.

Substituting this value for k_1 in (16), we have

$$Y_1(k_1 m, 0) = 1 - \frac{1}{3}\left(\frac{\pi m}{N}\right)^2 + \frac{1}{30}\left(\frac{\pi m}{N}\right)^4 - \cdots$$

[8] The line screens used in this work were made by photographic copying of an original ruled screen. The sharpness of line-to-space transition, as well as the relative widths of line and space, may be controlled readily with this method.

[9] This assumes the transmission of the television apertures to be uniform within the aperture boundaries. Otherwise a factor $T(\xi, \eta)$ must be inserted in the integrand of (5), as was pointed out in footnote reference 5 for the optical system.

[10] Setting $a = b$, which incurs no essential loss of generality.

which is a close approximation to (15) for the range of m which is of interest. The quality of the approximation is shown by the degree to which curve A matches curve C of Fig. 6. Thus we may write

$$Y_1(k_1 m, 0) \simeq Y_1^2(m, 0), \qquad k_1 = \sqrt{2}.$$

Similarly,

$$Y_1(0, k_1 n) \simeq Y_1^2(0, n), \qquad k_1 = \sqrt{2}.$$

Therefore, for the constants chosen, we may write

$$Y(m, n) \simeq Y_1(m, n) Y_2(m, n),$$

and the normal field expressions for the simulation system as given by (10), and the television system as given by (12) agree.

Spurious-Field Comparison

Continuing with the same constants as in the preceding discussion, we proceed to an evaluation of the television-image spurious field as given by the second term of (12). The meaning of this term may be expressed in the fact that an original subject component m, n of amplitude A_{mn}, gives rise to spurious components $m-\mu$, $n+\mu N$ at amplitudes $Y_1(m, n) Y_2(m-\mu, n+\mu N) A_{mn}$, μ being any positive or negative integer. The amplitude expression decreases rapidly with increasing absolute magnitude of μ. Thus the consideration of spurious components may be confined to those for which $|\mu| = 1$. Accordingly, we may neglect μ compared to m with negligible error.

The resulting spurious-component expression for the television image is m, $n \pm N$, at an amplitude of $Y_1(m, n) Y_2(m, n \pm N) A_{mn}$. This expression gives the same spurious-component indices as were found for the simulation system, so all that remains is to compare the corresponding amplitude expressions of both systems.

Omitting A_{mn} as being common to both amplitude expressions, the spurious amplitude factor for the television system with square apertures may be written as

$$Y_1(m, n) Y_2(m, n \pm N) = Y_1^2(m, 0) Y_1(0, n) Y_1(0, n \pm N).$$

The corresponding quantity for the simulation system is

$$Y(m, n \pm kN) \frac{T_1}{T_0} = Y(m, 0) Y(0, n \pm kN) \frac{T_1}{T_0}.$$

It was shown in the previous section that

$$Y(m, 0) = Y_1(k_1 m, 0) \simeq Y_1^2(m, 0), \qquad k_1 = \sqrt{2}$$

so that it is sufficient to compare

$$Y_1(0, n) Y_1(0, n \pm N) \quad \text{with} \quad Y(0, n \pm kN) \frac{T_1}{T_0}.$$

There are two elements of control in the latter expression which may be used to obtain agreement of these expressions. First, variation of the factor k (which may be remembered as determined by the positioning of the line screen) permits shifting of the expression along the axis of n. Second, the magnitude of the expression may be controlled by the factor T_1/T_0, which is determined by the nature of opacity variation across the lines and spaces of the line screen.[11]

Since the two expressions are fairly similar, these two adjustments permit a reasonably good agreement. A comparison is shown in Fig. 6, $Y_1(0, n) Y_1(0, n-N)$ being given[12] by curve D and $Y(0, n-kN)\ T_1/T_0$ (for the values $k=0.6$, $T_1/T_0=0.4$, and $k_1=\sqrt{2}$) by curve B. The divergence of the two curves for values of n above $0.7N$ is not important because of the small amplitudes of A_{mn} found in this region. The fact that the simulation curve B does not pass through the origin, for the choice of $k=0.6$, means that there will be some structure showing even when the original subject matter is a flat field. However, this effect is small.

Thus we find that there is a substantial agreement between the simulation and the television system, both as to normal and spurious components, for the square apertures assumed. A similar analysis holds for other types of apertures. If the transmitter and receiver apertures are alike in configuration and size, then the optical aperture should preferably be chosen to be of the same configuration,[13] and the focusing adjusted so that the optical confusion area is $\sqrt{2}$ (in linear dimensions) times that of either television aperture. The number of black lines in the line screen should always be chosen equal to the number of active scanning lines in the television system. Finally, the parameters k and T_1/T_0 should be chosen to obtain a match between the curves B and D of Fig. 6; that is, between the spurious-component amplitude factors of the optical and television systems for original subject components lying parallel to the scanning lines ($m=0$).

Frequency-Channel Limitation

The foregoing has neglected the effect of a finite frequency bandwidth in the television transmission channel. That an aperture characteristic may be used to simulate an electrical low-pass filter is well known, although the simulation has its limitations where the effect of a sharp cutoff is desired. Following the usual practice in this matter, it will be assumed that the actual electrical-filter characteristic may be replaced by an equivalent one having a gradual cutoff, which in turn may be simulated by an aperture characteristic. Then,

[11] A convenient method of controlling the T_1/T_0 ratio is to adjust, via photographic processing, the ratio of optical transmission of the "lines" and "spaces."

[12] Because of symmetry, only one sign of the $\pm$ need be considered.

[13] The more important consideration is that the optical aperture should have the same admittance in any direction as the television apertures. For instance, the effect of a scanning beam having nonuniform transmission over its area may be closely simulated by the shaped-hole type of aperture.

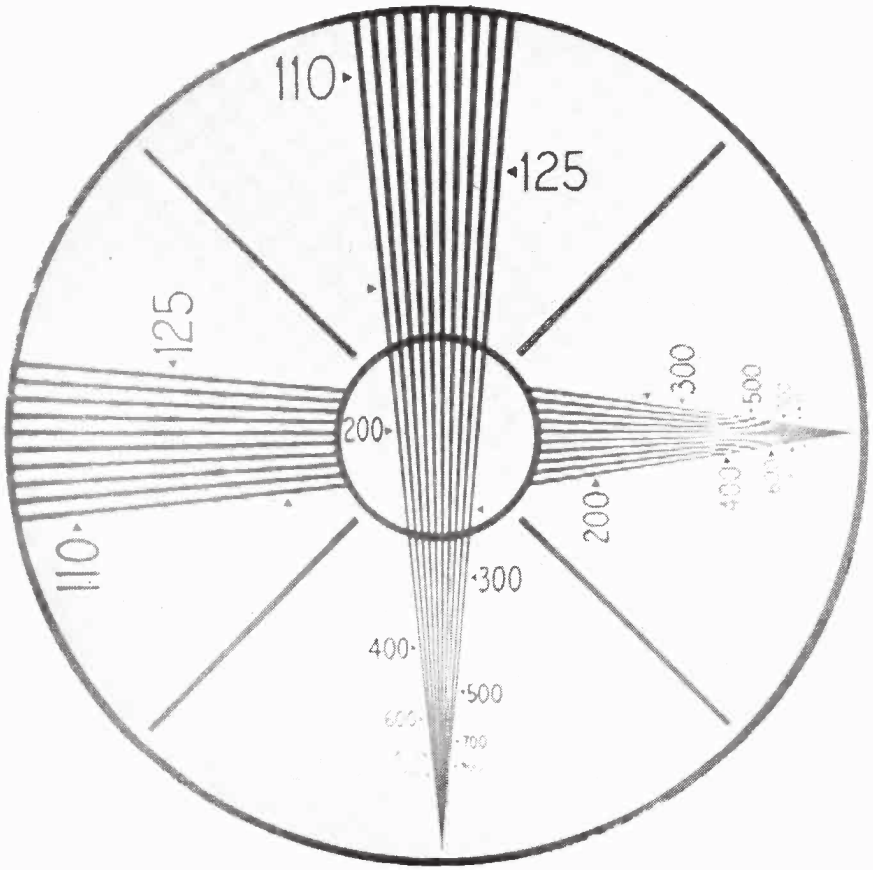


Fig. 7—Resolution diagram, with spurious structure.

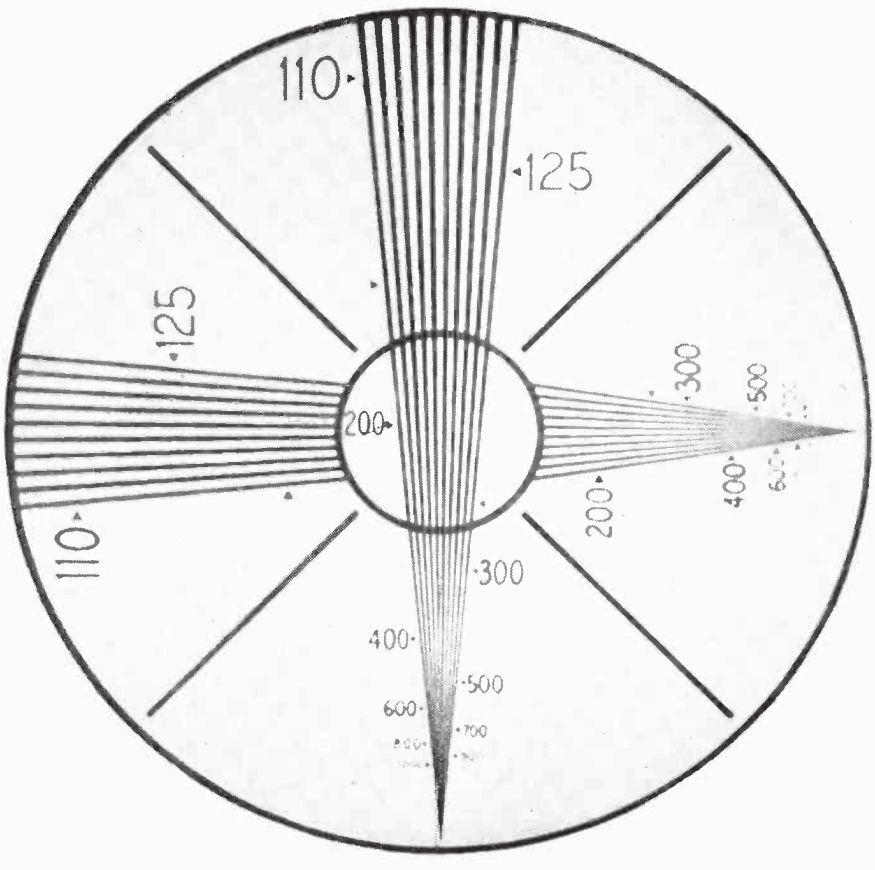


Fig. 8—Resolution diagram, without spurious structure.

since the principal effect of electrical frequency attenuation is upon the components of the image perpendicular to the scanning, the frequency limitation may be taken into account by increasing the horizontal dimension (scanning assumed horizontal) of the confusion area of the simulation system over the value arrived at from previous considerations.

This is exemplified in the square-aperture television system by the following procedure. The effect of the

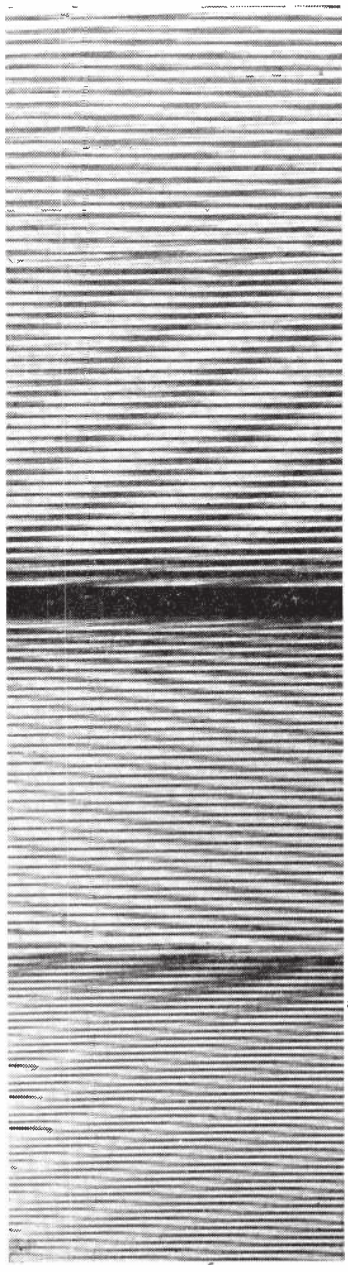


Fig. 9—Parallel lines, with spurious structure.

filter cutoff in the direction of scanning is evaluated as that due to a rectangular aperture of length (in scanning direction) $2c'$. Then if $2c$ is the length of the transmitter and receiver apertures, the required horizontal dimension of the optical simulation aperture is

$$2c'' = \sqrt{(2c)^2 + (2c)^2 + (2c')^2}.$$

VI. Discussion and Results

Photographs of simulated television pictures obtained with the apparatus of Fig. 1 are shown in Figs. 7, 9, 11, 13, and 14. In each of these pictures the scanning apertures of the equivalent television system have been taken to be squares of side equal to the scanning-line pitch. No allowance for electrical filtering has been

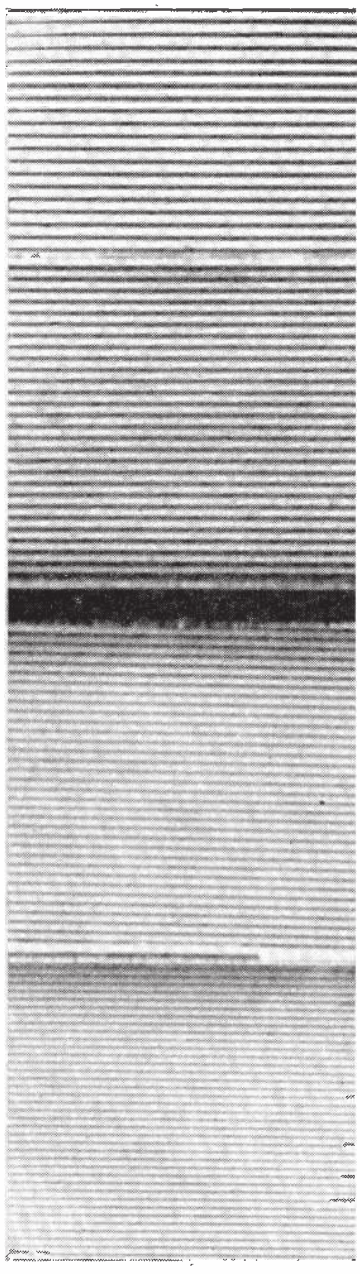


Fig. 10—Parallel lines, without spurious structure.

made, the aperture attenuation being considered as the cutoff of the television channel.[14] The other parameters

[14] Within the limitations previously pointed out, the inclusion of electrical frequency-attenuation effects would have been a simple matter. However, because of the unavoidable resolution loss in reproducing the photographs, further refinements were considered unnecessary.

are approximately those given previously for curves *A* and *B* of Fig. 6.

Fig. 7 shows a simulation picture of a resolution diagram, there being the equivalent of approximately 360 scanning lines across the height of the picture. The effect of the spurious components, as given by the second term of (10), may be seen in the steps along the lines of the horizontal wedge, in the spurious pattern in the right half of this wedge, and in the serrations appearing on the numbers. It may be observed that the resultant resolution of lines in the horizontal wedge is markedly lower than that for the vertical wedge.

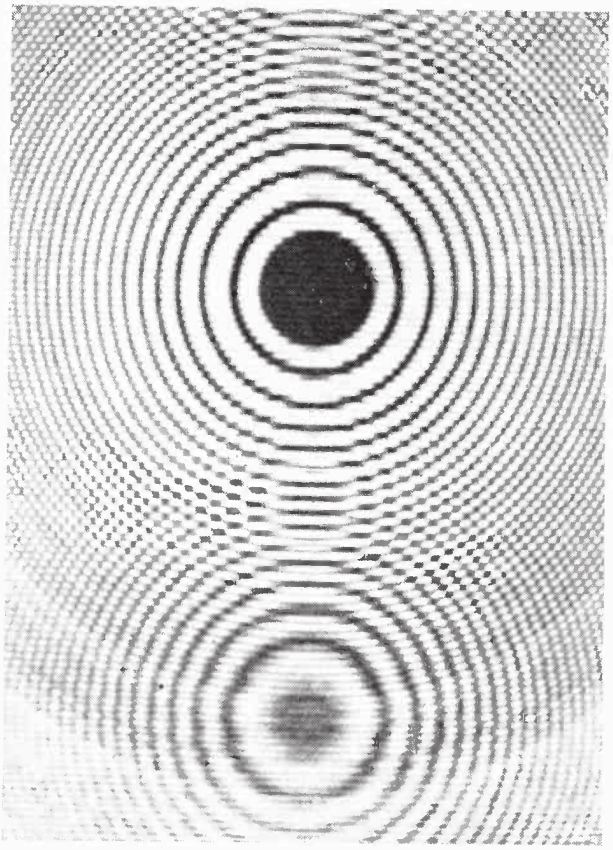


Fig. 11—Zone plate, with spurious structure.

An interesting comparison may be made between Fig. 7 and Fig. 8. Fig. 8 is a simulation picture, purporting to represent the same television picture as Fig. 7, made by using an out-of-focus optical system omitting the scanning structure. In order to take account of this omission of spurious components, the height of the figure of confusion has been increased by a factor of 1.4, an average of the factors suggested by various investigators[15] to take account of the vertical-resolution degradation due to scanning structure. It may be seen that a completely satisfactory equivalence factor[16] expressing the effect of the spurious components in terms of resolution degradation may be difficult to arrive at in general.

Fig. 9 is a simulation photograph of four sections of parallel lines, each having a different pitch, arranged so that the subject lines form a small angle with the scanning lines. There are approximately 400 lines contained in the picture height. Fig. 13 is the corresponding simulation picture omitting scanning structure and having a 1.4-times-greater vertical aperture.

Fig. 11 is a particularly interesting illustration of the peculiar effects arising from the spurious component field. The original subject matter was the zone plate of

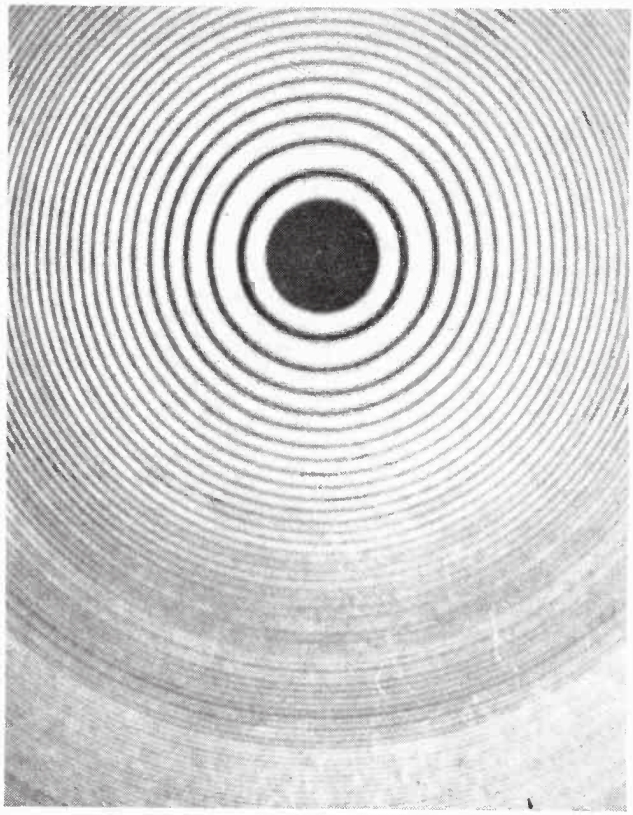


Fig. 12—Zone plate, without spurious structure.

Fig. 12, the spurious structure giving the effect of a ghost image or echo of the original.[17] Beats between this spurious image and the original may also be observed. The corresponding nonstructure simulation picture is shown in Fig. 12.

Figs. 10 and 11 are simulation pictures[18] of 441-line television pictures which have about 15 per cent vertical blanking. The scanning structure shows up throughout the outdoor scene, and is evident in the portrait of the girl, around the eyes, teeth, and hat.

Fig. 15 is an out-of-focus picture of the zone plate of Fig. 12, which illustrates the significance of aperture

[15] See footnote reference 3. Baldwin lists the values which have been obtained for this factor.

[16] The estimates of this factor were usually based on the use of general subject matter, rather than the specialized type of subject used above.

[17] A picture similar to Fig. 11, showing a zone plate after transmission over a telephotograph system is given by Mertz and Gray. (See footnote reference 6.)

[18] Scene of Fig. 13 reproduced by courtesy of Loucks and Norling. Scene of Fig. 14 reproduced by courtesy of Fox Movietone News.

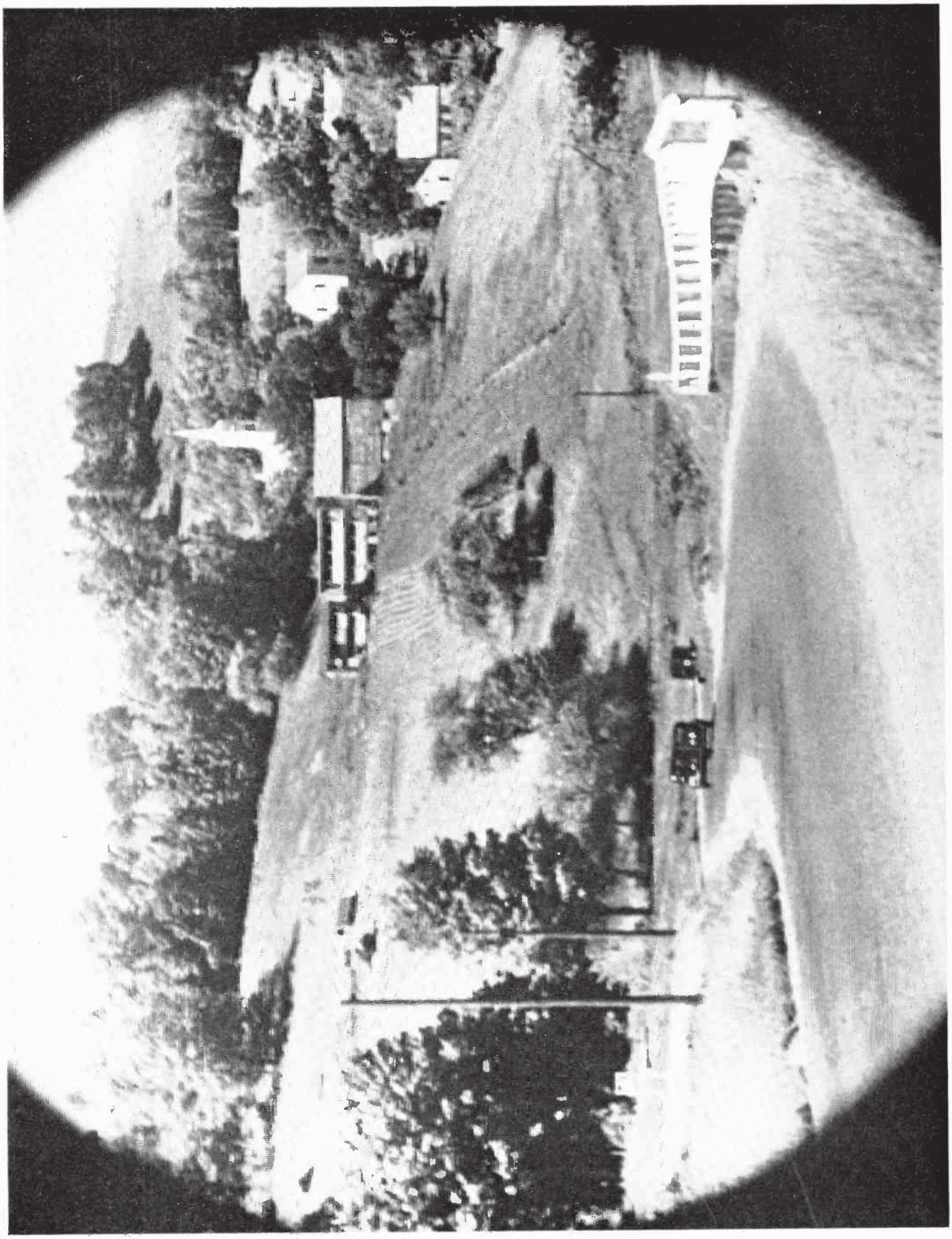


Fig. 13—Simulation picture of 441-line television picture.

Fig. 14—Simulation picture of 441-line television picture.

admittance characteristics of the type shown in curve *A* of Fig. 6. The confusion area is square and is arrayed with its sides horizontal and vertical. The "waves of sharpness," which may be seen principally along vertical or horizontal radii as the pitch of the rings diminishes, correspond to the lobes of the aperture admittance curve appearing between successive crossings of the zero axis. The first crossover point of the aperture admittance characteristic was found very useful in checking experimentally the size of confusion area. That practically no lobular resolution is visible along 45-degree radii is due to the fact that the aperture appears as diamond-shaped along these directions, the lobes of a diamond aperture admittance characteristic being very small compared to those for a square or rectangle.

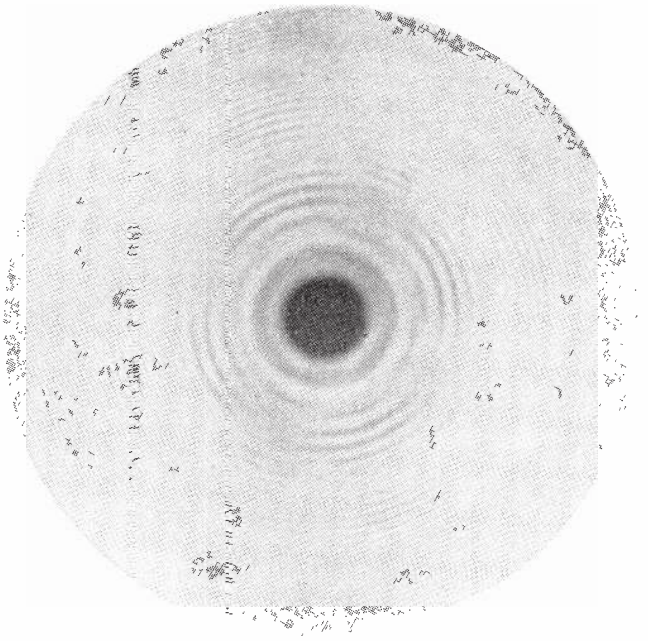


Fig. 15—Zone plate; illustration of aperture effect.

There are several alternative optical arrangements which may be used for producing simulation images similar to those discussed above. One variation, which permits the projection of large pictures viewed on a reflecting screen, is obtained by placing the line screen behind the projector lens close to the film plane. Another variation, of interest because it produces an almost exact simulation, may be obtained by using a line screen in conjunction with two out-of-focus transformations in tandem. However, this would be suitable only for photographic work, due to the low picture brightness obtained with this arrangement.

Simulations of both 240- and 441-line television pictures, still and motion, have been set up, and on numerous occasions compared with the images produced by the corresponding television systems. The fundamental similarity between the simulation and television images was strikingly apparent even at close viewing distances; and the quantitative comparison agreed with that predicted by theory. Simulations of 525- and 625-line television images have also been made. The conversion of the simulation picture from one grade of television image to another was very simple, requiring only a change of line screens and readjustment of the focusing dial.

VII. Appendix

Diffraction Calculation of an Out-of-Focus Optical System for a Rectangular Aperture

The geometrical theory which has been used in the paper to describe the figure of confusion of the optical system is subject to appreciable error for planes near the sharp-focus plane. In order to investigate the magnitude

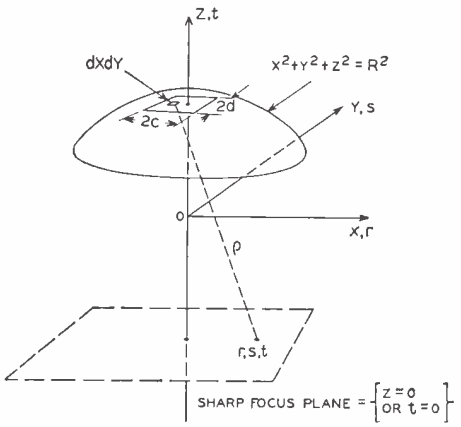


Fig. 16—Diffraction calculation of the confusion area for an out-of-focus optical system.

of the error, a diffraction calculation of the system has been made. The line screen is omitted from the calculation, since a simple estimate shows diffraction effects arising from this source to be small for the dimensions used.

The formulation of the diffraction solution follows Fig. 16. It is assumed that the wave front of the light emerging from the lens, due to a point source located on the optical axis at the film plane, is a section of a sphere with center on the optical axis at the sharp-focus plane. The radius R of the sphere is the image distance of the optical system. The active portion of the spherical wave front is that section bounded by the rectangular aperture of sides $2c$ and $2d$ oriented parallel to the x and y axes, respectively. Then, neglecting the varying inclination of surface elements of the sphere over the aperture boundary, the light amplitude at any point of the image space r, s, t may be written as

$$a = \iint_{\text{aperture}} \sin 2\pi \left(\frac{\tau}{T} - \frac{\rho}{\lambda} \right) dx dy,$$

where ρ = the distance from a surface element $dxdy$ to the point r, s, t,
τ = time
λ = wavelength of light (assumed monochromatic).

By assuming the maximum values of the variables x, y, r, s, t to be small compared to R, the following result is obtained for the light intensity at a point r, s, t. Neglecting constant factors, we find,

$$J = \left(\left[C(a_1 + a_2 r) + C(a_1 - a_2 r)\right]^2 + \left[S(a_1 + a_2 r) + S(a_1 - a_2 r)\right]^2\right) \cdot \left(\left[C(a_3 + a_2 s) + C(a_3 - a_2 s)\right]^2 + \left[S(a_3 + a_2 s) + S(a_3 - a_2 s)\right]^2\right) \qquad (17)$$

where $C(\ )$ and $S(\ )$ are the Fresnel integrals, being given by

$$C(x) = \int_0^x \cos\frac{\pi}{2} v^2 dv,$$

$$S(x) = \int_0^x \sin\frac{\pi}{2} v^2 dv,$$

and where, for positive values of t,

$$a_1 = c\sqrt{\frac{2t}{\lambda R(R - t)}}$$

$$a_2 = \sqrt{\frac{2R}{\lambda t(R - t)}}$$

$$a_3 = a_1\frac{d}{c}.$$

For negative values of t, the absolute magnitude of t must be used in (17) and in the following formulas.

$$a_1 = c\sqrt{\frac{2t}{\lambda R(R + t)}}$$

$$a_2 = \sqrt{\frac{2R}{\lambda t(R + t)}}$$

$$a_3 = a_1\frac{d}{c}.$$

Fig. 17 shows a plot of J in the plane $t = -2$ inches, for $s = 0$ and the representative values $R = 76$ inches, $c = d = 1/2$ inch, $\lambda = 5000$ angstrom units. The aperture admittance corresponding to this intensity distribution is shown in Fig. 18, along with the admittance curve obtained from geometrical considerations. There is seen to be very good agreement between the two, so that the geometrical theory may be used for the given dimensions without appreciable error. For values of t less than one inch, however, the error becomes noticeable, and should be considered.

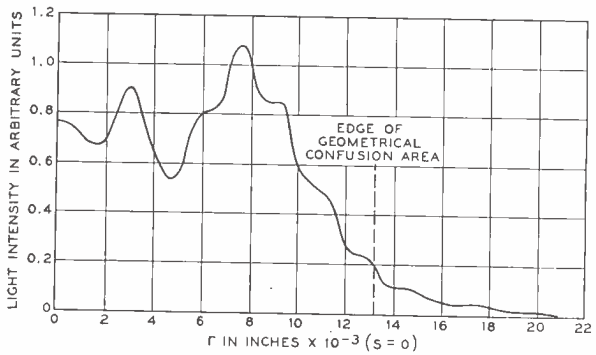


Fig. 17—Diffraction calculation. Light distribution in the out-of-focus plane $t = -2$ produced by an axial point source in the film plane.

$R = 76$ inches
$c = d = \frac{1}{2}$ inch

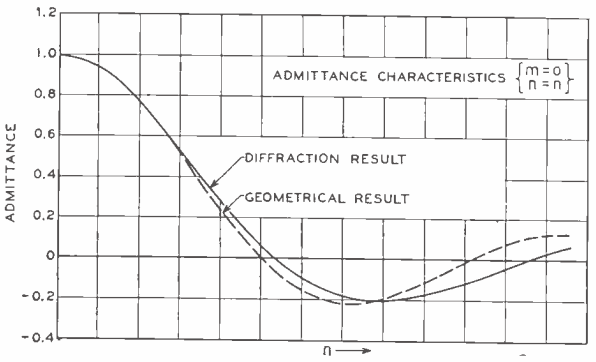


Fig. 18—Comparison of geometrical and diffraction admittance calculations. Solid curve calculated from curve of Fig. 17.

Problems in the Manufacture of Ultra-High-Frequency Solid-Dielectric Cable*

A. J. WARNER†

Summary—This paper deals with the various types of semiflexible solid-dielectric transmission lines suitable for use at ultra-high frequencies. Five general types are described, and their applications discussed. These are (a) coaxial, (b) dual, (c) dual-coaxial, (d) low-capacitance, and (e) high-impedance. Types (a) and (b) are general-purpose lines, while type (c) is used in direction-finding equipments, instrument-landing systems, etc. High-impedance cables find use in cathode-follower and special delaying circuits.

The manufacture of these transmission lines is discussed, and the various problems associated with extruding and braiding examined. The practical question of penetration of the braid into the dielectric and jacket is considered, and the recent steps taken to eliminate this problem discussed.

The contribution of the individual components of the cable to the total loss is examined, and an apparatus described which enables a direct measurement of braid resistance to be made at 150 megacycles. A typical example is given for RG-8/U cable, showing close agreement between the measured total loss of the line and the loss obtained by a summation of the individual losses of dielectric, inner conductor, and braid. The effect of varying the braid construction is demonstrated. The electrical testing of high-frequency transmission lines poses some problems, and a brief description, limited for security reasons, of the various tests and equipments is given. The author concludes by recommending immediate consideration of standardization problems in this field.

Introduction

THE VERY rapid advances made in the electronic field in the last decade, and particularly those necessitated by the exigencies of war, have brought many new and interesting developments to fruition. For obvious reasons, many of these developments must remain closely guarded secrets until after this period of international conflict, but some of them can now be discussed in general terms, and the progress made outlined. In this paper it is proposed to deal briefly with a not very spectacular, but nevertheless highly important, component of modern electronic equipments, the ultra-high-frequency solid-dielectric cable. Such cables have now attained a noteworthy place in the components list, and are destined to play a more important role in the future.

The Nature of Solid-Dielectric Lines

One of the principal factors necessitating the development of solid-dielectric semiflexible cables was the design of electronic equipments for moving vehicles such as tanks, airplanes, and trucks; and for demountable equipments such as instrument-landing systems, direction finders, gun-directing devices, etc. These equipments called for cable components that would be light, portable, easily assembled and disassembled, semiflexible, and having few (if any) maintenance problems. Not the least of the requirements, however, was the ability to obtain such cables in large quantities with the minimum of expansion of production facilities.

The standard rigid line, consisting essentially of a center conductor coaxially placed in a solid-copper tube and supported by rigid discs, washers, or spacers of dielectric material uniformly spaced, is well known. To obtain satisfactory operation of such lines, it is necessary to use somewhat complicated and expensive "plumbing" methods to join the lines to equipments and themselves, and to install a special nitrogen or inert-gas atmosphere under pressure to prevent "breathing" of the line and consequent moisture deposition inside the structure. Such an installation is costly, but, where the assembly is permanent, affords highly satisfactory operation, since it can be rigidly installed and with periodical maintenance check-ups can be expected to maintain its original qualities. The mechanical construction of these lines enables a high degree of uniformity of electrical characteristics to be obtained, and because of their rigid construction from solid conductors, the exact value of impedance and attenuation can be calculated before the line is even constructed. With semiflexible ultra-high-frequency transmission lines, however, the maintenence of uniform electrical characteristics is much more difficult, particularly when it is remembered that such lines are expected to operate over a wide temperature range, -40 degrees centigrade to $+80$ degrees centigrade, to be capable of much abuse in the field, and to be adaptable for the many different types of equipment now in use.

At the present time, semiflexible cables for ultra-high-frequency use fall into the following general types: coaxial, dual, dual-coaxial, low-capacitance, and high-impedance.

In the case of coaxial types, we have a center conductor insulated with a synthetic dielectric, a braid which acts as the return conductor and also as an electromagnetic shield, and an outer protective sheath of synthetic resin. In certain cases, especially for shipboard use, where installation in conduit is a requisite, a galvanized steel or aluminum armor is put over the sheath, which affords both mechanical protection and additional electrical shielding. The dual types are similar to the coaxial types, except that the two inner conductors are imbedded in the primary insulation. The dual-coaxial types of cables are special designs for specific problems, such as that in connecting up the antenna arrays of

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† Federal Telephone and Radio Corporation, Newark, N. J.

instrument-landing systems, in certain direction-finding equipments, etc.

The low-capacitance cable consists of a center conductor held in position in a thin-walled tube of dielectric by an insulating thread spirally wound around the center conductor. Over the tube is put the usual braid and jacket. Such a design, by virtue of its relatively large volume of air, has a low effective dielectric constant, and therefore the capacitance per foot is also low.

The high-impedance type of cable is a special design for those equipments where an impedance of the order of 1000 ohms is required in the cable. Such a cable comprises an inert supporting core on which is wound a close-lay spiral of enameled wire. Over this is put a synthetic insulation and then the conventional braid and sheath. Fig. 1 shows the various types of cables discussed above.

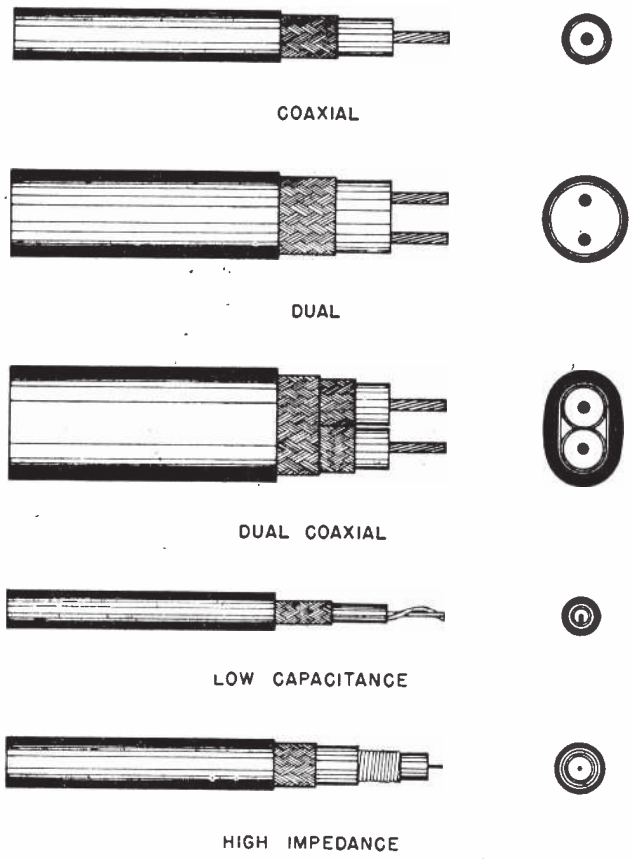


Fig. 1.—General types of ultra-high-frequency cables.

The Manufacture of Solid-Dielectric Cables

The chief operations in the manufacture of cables for use at ultra-high frequencies are those of extrusion and braiding. Extrusion is a process for forcing materials in a semisolid state through a suitable orifice such that a definite shape is obtained. The first operation in cable manufacture is the extruding of the primary insulation on the center conductor, which is done by means of a specially designed plastics extruder. Such an extruder consists essentially of a heated cylinder through which the insulating material is forced by means of a rotating screw, and in which the material is brought to the right state of plasticity, a breaker-plate assembly which serves to build up pressure and to ensure that all undispersed or foreign matter is removed from the material, a cross head through which the center conductor to be insulated is fed, and a tip and die assembly which forms the insulation around the center conductor to the desired shape. The various parts of the machine can be seen by reference to Fig. 2. Although at first sight it might appear that this process is but little different from that employed in the manufacture of conventional rubber-insulated wires, the fact that we are dealing with plastic materials of higher softening point and different degrees of plasticity, necessitates machine modifications, while the necessity for maintaining a high degree of uniformity introduces manufacturing problems of no mean extent. It is obvious that, for successful service use, certain electrical parameters must be closely controlled, and of these parameters, the characteristic impedance introduces the first problem from the mechanical point of view.

Since it is desired to keep the characteristic impedance of the cable as uniform as possible and at a fixed value, the ratio of the diameter of the inner conductor to the diameter of the outer conductor must be held to a close tolerance. For most applications, it has been decided that, with a nominal impedance of 50 ohms, a tolerance of ± 2 ohms is the maximum permissible. To achieve this, it is necessary to hold the diameter of the dielectric to within ± 15 mils. Since it is necessary during manufacture to have some little leeway in tolerance, it means in practice that to keep rejections to a minimum, even tighter dimensional tolerances must be maintained. When it is recognized that this tolerance must be maintained while the cable is being produced at speeds up to 100 feet per minute, it will be appreciated that the equipments must be functioning correctly, the operators well-trained and supervised, and constant production engineering maintained.

To ensure uniform values of attenuation, and particularly to maintain the lowest values possible, the dielectric material must be rigidly inspected before use, and handled with the greatest of care to avoid contamination. Since the velocity of propagation is a function of the dielectric constant of the insulating material, care must be taken in manufacture to avoid the presence of voids or discontinuities in the dielectric and to see that the material is applied uniformly as regards density.

When the frequency of operation becomes very high, indeed, we find that additional problems are present. At these frequencies, the presence of any form of discontinuity will cause trouble due to reflections and standing waves. This may occur even though the cable is well within the tolerance values for size called for in the specification. To overcome such problems, the nature and extent of which are only just becoming very painfully apparent, the highest degree of skill will be

required from all phases of engineering, the raw-material experts, the mechanical designers, and the electrical engineers.

After the extrusion of the primary insulation, the braid or outer conductor is put on by a process referred to as "braiding." Two main types of braiding machines are in operation, the so-called "Wardwell" type, and the "New England Butt" type. In the Wardwell machine we have two carriages, each having twelve bobbins containing the braid wires, rotating horizontally in opposite directions, the individual bunches of wires from the bobbins being deflected by guides to interweave them in the form of a basket weave. Such a braider is shown in Fig. 3. For large cables, the New England Butt type is often employed; here the bobbins, usually forty-eight in number, are mounted vertically and rotate in a horizontal plane around the periphery of the machine, forming a basket weave around the centrally located cable.

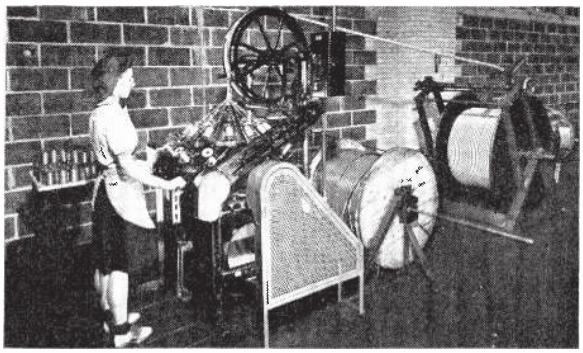


Fig. 3—Copper-wire braiding machine.

with polyethylene, the braid wires may have a tendency to imbed in the dielectric, particularly if the cable has been heated or if the braid has been designed with a relatively short lay and applied with a high tension. It is even more common for the braid wires to be imbedded

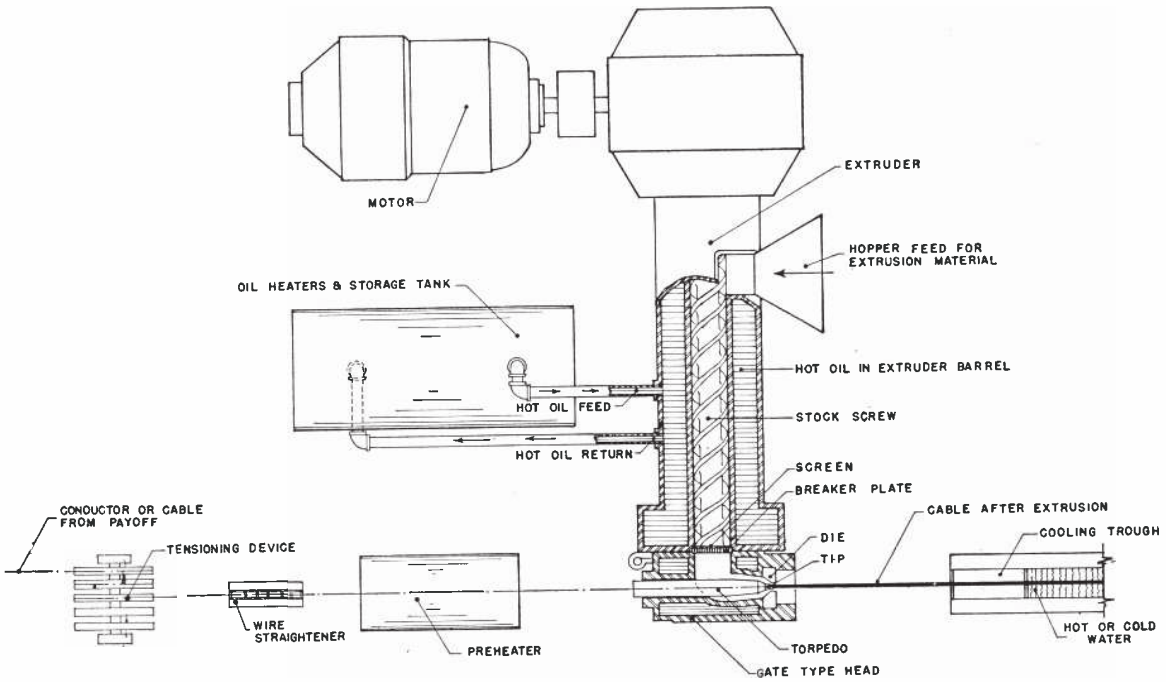


Fig. 2—Schematic cross section of extruder.

In general, apart from design characteristics, the problems in braiding are purely mechanical, and the success of good braiding depends chiefly on the care with which the individual wires are wound on the bobbins for braiding.

There is one problem concerning the braid which is of particular interest to the equipment manufacturer, and that is the adhesion or penetration of the braid to either the primary insulation or the jacket. When softer dielectrics than the polyethylene now standard were employed, it was quite common for the braid wires to be buried so deeply in the dielectric, due to the tensions exerted during braiding, that it was a matter of great difficulty to strip the braid wires back preparatory to connector assembly. It sometimes happens that even in the jacket; this is caused by applying the plastic jacketing material to the braided wire in a very soft state and through a tip-and-die combination causing the hot plastic to be forced through the interstices of the braid. On cooling, the braid wires are often found to be completely imbedded in the jacket. In such cases, it is almost impossible satisfactorily to prepare a cable end for connector assembly. The use of special tubing tips and dies which serve to lay a tube of the protective jacketing material on the braid under the right pressure, has overcome this problem. The presence of jacketing material in the braid also serves to introduce additional attenuation losses in the line and to give it attenuation instability with flexing.

The sheath, or jacket, is applied with the same type

plastic tuber as the primary insulation, and affords neither more nor fewer problems than those discussed under that subject.

Design Components

One of the most important factors affecting the design of a high-frequency cable is the nature of the dielectric material to be employed. Such a dielectric has to have the lowest attainable electrical losses, and these losses must be substantially constant over a wide frequency band and a considerable range of operating temperatures. Apart from these electrical requirements, the dielectric must also be capable of installation at temperatures as low as −40 degrees centigrade and yet support the weight of the center conductor at elevated temperatures of +85 degrees centigrade without flow. The search for suitable materials has been going on for some considerable time, and it cannot yet be said that a completely satisfactory material has been developed. At the present moment in this country and Great Britain, the preferred insulation is polyethylene, a high-molecular-weight hydrocarbon of the paraffin series. The properties of this material are given in Table I. This material is

Table I

Polyethylene, Average Properties

Tensile strength, pounds per square inch	1700
Coefficient of thermal expansion	10.5×10^{-5}
Rockwell hardness	R13
Specific gravity	0.92
Elongation, per cent	500
Heat distortion point, degrees Fahrenheit	140
Water absorption after 24-hour immersion, per cent	0.01
Dielectric strength, volts/mil, 3 to 15 mils thick	1000 to 1500
Volume resistivity, ohm-centimeters	10^{17}
Dielectric constant	
60 cycles	2.25 to 2.27
1000 cycles	2.25 to 2.27
1 megacycle	2.25 to 2.27
1000 megacycles	2.65 to 2.27
Power factor	
60 cycles	0.0002 to 0.0004
1000 cycles	0.0002 to 0.0004
1 megacycle	0.0002 to 0.0004
1000 megacycles	0.0002 to 0.0004

now being manufactured in large quantities, and a high degree of uniformity is obtained. Its low value of power factor (of the order of 0.00030) and its attendant low dielectric constant (approximately 2.27) are maintained over a wide range of frequencies, while its flexibility at low temperatures and its rigidity at elevated temperatures are satisfactory.

By skillful operating technique, a high degree of extrusion precision can be obtained, which enables good control of impedance and other electrical parameters of the final product to be maintained.

The center conductor of a high-frequency solid-dielectric cable is either concentric-lay, stranded, or solid, dependent upon the general considerations applying to its use. Stranded conductors are chiefly employed where the greatest degree of flexibility of the cable is required; solid conductors are generally employed where the lowest electrical losses are necessary and also where a cable is desired to have the highest value of initial corona-starting potential. In order to reduce the losses still further, it is common practice now to use silver-plated conductors. For certain applications, it is desirable to have a cable which has a high loss per unit length, and for these cables, the center conductor usually consists of a nichrome wire. To maintain constancy of impedance, it is necessary for the center conductor to be manufactured with a high degree of uniformity, and some of the troubles of the earlier high-frequency solid-dielectric lines have been traced back to irregularities of stranding and dimensions. The braid consists of a basket weave of wires which vary in number, size, and mode of application, dependent on the size of the cable and the use to which it is to be put. For the smaller size of cables, it is usual to have 24 separate ribbons of braid wires in the construction, each ribbon comprising six to ten individual wires of no. 33 or no. 34 American Wire Gauge. The lay of the braid, or number of ribbons of wires per inch, is determined by the electrical and mechanical properties required. Since at the frequencies employed the current travels on the surface of the wires, it is obvious that the fewer the jumps the current has to make per unit length, the lower the loss. On the other hand, the shorter the lay of the braid, the more flexible is the cable, and the more it is able to withstand repeated flexings without failure or deterioration of electrical characteristics.

It must be confessed that many of the braid designs currently employed were chosen for expediency rather than from a sound engineering design, but constant improvement is being made, and it is to be hoped that we will be able in future years to design cables a little more scientifically than in the past.

Since plain copper wire has a tendency to oxidize in air and also to corrode in the presence of electrolytes such as salt, it is sometimes found advisable to use tinned-copper wires for the braid instead of plain copper wire. The presence of oxidation and/or corrosion products on copper-braid wires not only causes an increase in the electrical loss of the cable, but also gives rise to fluctuating readings on equipments due to contact-resistance variations when the cable is shifted or flexed. To lower the losses, and also to avoid this variation of contact resistance, especially for cables used as test leads in precision testing equipments, it is now quite common to use a silver-plated copper-braid wire.

In certain applications, where good shielding is required, a second braid is sometimes employed. In such double-braided cables it is usual to take advantage of the electrical properties to be obtained by the use of a long-lay braid, by employing as long a lay as practicable for the inner braid, maintaining the outer braid with a short lay for mechanical considerations. Consideration has been given, from time to time, to the use of more than two braids for additional shielding, but it has now been demonstrated that the advantages gained by the employment of a third shield are not sufficient to warrant the additional expense and problems of manufacture and installation. Such shielding problems are best

handled by investigating the over-all shielding of the individual equipments concerned.

The jacket, or sheath, acts primarily as a protection of the cable structure therein. It should be flexible, resistant to abrasion, oil, gasoline, water, hydraulic-brake fluids, etc., and should also preferably be non-inflammable. The most commonly used jacketing materials for high-frequency cables are plasticized vinyl compounds such as vinyl chloride or vinyl chloracetate, sold under the trade names of Vinylite and Geon. It has recently been found that, where the greatest degree of constancy of operation of high-frequency solid-dielectric cables is required, a special type of vinyl jacket must be employed. Such a jacket has been developed and is now in service on these special cables.

To increase the mechanical protection of lines, particularly for naval use, an outer armor is sometimes employed. This is preferably of galvanized steel, but during the wartime emergency, aluminum wire has been substituted for the galvanized steel. Such armored cables are painted with an aluminum paint to fill the interstices in the armor and thus facilitate their watertight installation through bulkheads.

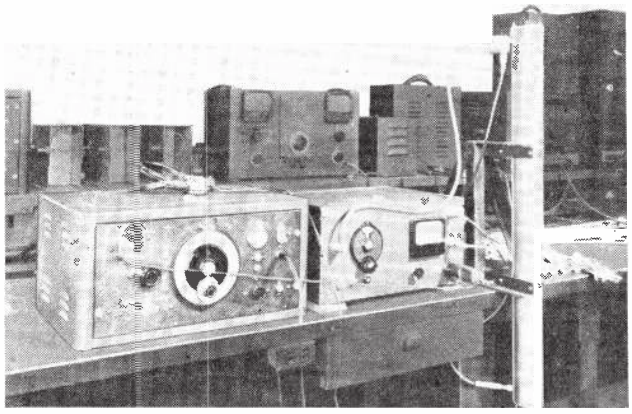


Fig. 4—Apparatus for measuring braid resistance.

Of great interest to the radio engineer is the contribution of the various components of the cable to the total measured loss or attenuation, and particularly, how this varies with frequency.

It is well known that the dielectric losses are a direct function of the electrical properties of the insulation and frequency of operation, and thus a measurement of the power factor and dielectric constant at those frequencies enables the contribution of the dielectric to the total loss to be calculated. Thus, taking polyethylene as an example: the power factor of polyethylene at 400 megacycles is 0.00030 and the corresponding dielectric constant is 2.27. The loss due to the dielectric is therefore $\alpha_{400} = 2.78 \times \sqrt{2.27} \times 0.00030 \times 400$ decibels per 100 feet $= 0.503$ decibel per 100 feet. Taking a standard cable, for example RG-8/U, the measured loss of this cable at 400 megacycles is 5.0 decibels per 100 feet. The contribution to the over-all loss by the center conductor and braid is therefore 4.5 decibels per 100 feet. To separate the loss due to the center conductor from that due to the braid, and to determine the effects of changing the lay of the braid on the coverage has been a somewhat complex problem and only empirical calculations have hitherto been made. Recently, however, Muller and Nordlin of the Federal Telephone and Radio Laboratories have developed an equipment (Fig. 4) which enables such measurements to be made, and the preliminary results are very valuable for future design work. At the present moment, due to lack of suitable oscillators, it is not possible to measure at frequencies other than 150 megacycles, but it is hoped shortly to have such oscillators and to be able to extend the usefulness of the equipment. Thus, taking the standard RG-8/U cable, which has a measured attenuation at 150 megacycles of 2.60 decibels per 100 feet, the contribution of the individual components of the cable is:

Dielectric component	= 0.189 decibel	per 100 feet
Center conductor	= 1.58 decibels	per 100 feet
Braid	= 0.903 decibel	per 100 feet
Total	2.67 decibels	per 100 feet.

It will be seen that the agreement is very good.

It is a well-known practical observation that the attentuation of a transmission line can be improved by increasing the lay of the braid wires; that is, by decreasing the number of braid-wire crossovers per inch. It has also been a matter of great interest, particularly from a raw-material conservation standpoint, to determine how the wire coverage, that is the ratio of surface of the dielectric covered by the braid wires to the total surface, affects the attentuation loss. Table II shows some

TABLE II

Lay angle in degrees	Loss in decibels per 100 feet	Coverage in per cent	Loss in decibels per 100 feet
63.4	1.94	97.75	0.888
55.9	1.36	93.30	0.856
47.7	1.22	86.70	0.825
38.6	1.05	77.90	0.804
26.1	0.888		

of the results so far obtained. It will be seen that the loss due to the braid is markedly affected by the lay of the wires as would be expected, but that the per cent coverage is not a critical factor.

This particular experimental equipment will be of great use in studying the effect of different materials, such as silver-plated copper, and tinned copper versus plain copper wire, and also in studies to determine the effects of corrosion and/or flexing on the attenuation of transmission lines.

Testing Problems

The testing problems encountered in high-frequency solid-dielectric cables are of two types. First, those concerned with production testing, and second, specialized

problems concerned with the particular design and utilization of the cable type.

In general, factory production testing is chiefly a problem of the application of known techniques. It is necessary, however, to devise and build test equipments which are very rugged, quick acting, and as foolproof as possible. It must also be remembered that the equipments are to be operated by persons having little, if any, electrical background, and whose knowledge of high-frequency radio problems is substantially nil. The chief factory tests made are: capacitance, velocity of propagation, characteristic impedance, attenuation, dielectric strength, initial corona-starting voltage.

Capacitance is very conveniently measured at 1000 cycles and affords no special problem since standard equipment is employed.

The velocity of propagation is usually determined by measurement of the frequency at which a known length of cable, usually $\frac{3}{4}$ of a wavelength, resonates when terminated in an open circuit. Cables having a high attenuation cannot be measured by this method, because the resonance effects are not prominent enough to give an accurate determination. A convenient testing equipment, shown in Fig. 5, was developed by the Naval

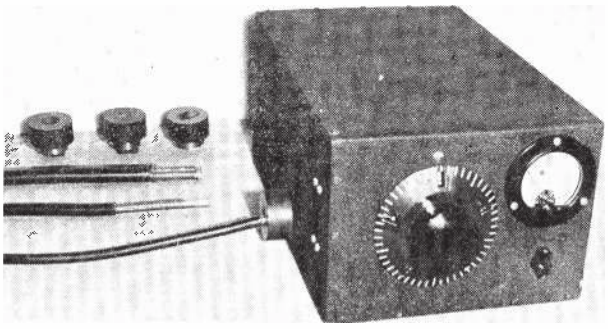


Fig. 5—Velocity-of-propagation meter.

Research Laboratories. It consists of an oscillator, variable around 100 megacycles, coupled loosely to a noninductive loop attached to one end of the cable under test. This loop is tunable by a variable trimmer capacitor. Resonance is indicated by a dip in a grid meter. In the so-called "V-P Meter," the loop circuit, and the oscillator circuit are tracked and controlled by a single dial. When the cable under test is inserted into the meter, resonance occurs and is indicated at one position only on the dial which is calibrated to read velocity of propagation directly.

The characteristic impedance is calculated from the measured capacitance and velocity of propagation by the usual formula. This calculation makes two assumptions which are justified: (1) That the effect of losses on characteristic impedance is negligible, which is true except for the lowest frequencies; (2) that the depth of penetration of current into the conductors is negligibly small, which is true for frequencies above 1 megacycle.

Fig. 6 shows the apparatus used by Federal Telephone and Radio Corporation for the measurement of attenuation at frequencies of 100, 200, 300, and 400 megacycles. The basic design was developed by the Naval Research Laboratories but was modified to give an equipment more suitable for production use and capable of higher precision. In this method, energy from a generator is fed directly into a calibrated vacuum-tube voltmeter and subsequently through the transmission line under test into the same voltmeter, the ratio of the two voltmeter readings giving the loss of the line. A diode voltmeter operated with a large input signal is employed to minimize transit-time effects and is calibrated at 60 cycles directly in decibels. The power output of the generator is adjusted with no transmission line connected until the voltmeter reads zero decibels. The generator is coupled to the input end of the line through a pair of critically coupled tuned circuits, and the output end of the line similarly coupled to the voltmeter, the critical coupling properly terminating the line in its characteristic impedance and eliminating reflection losses. The loss in the line can then be read directly in decibels. The spiral delay lines, or high-impedance lines, have relatively high attenuation values per unit physical length, and are

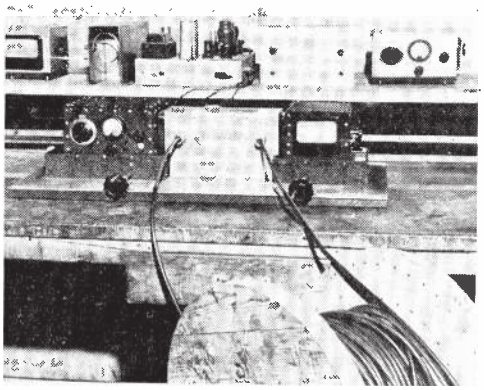


Fig. 6—Equipment for measuring the total attenuation of a transmission line.

therefore not capable of measurement on the above described equipments. An equipment, operating at 5 megacycles and measuring the resonant rise of voltage occurring when a sample of cable, an odd number of wavelengths long, is terminated in an open circuit, has been developed in our laboratories and has given very satisfactory operation. This method is based on the previous work of the Industry Service Division of R.C.A. Laboratories for use with television lines.

For cables designed for operation at high voltages, it is necessary to obtain as high an initial corona-starting potential as possible. Corona is a momentary discharge irregularly repeating at a rapid rate, and is caused by the ionization of air or other gaseous inclusions in the dielectric due to high electric-field strength. The corona-starting potential can be measured by a variety of means, but a convenient method comprises detecting the transient in the 60-cycle wave by means of an oscilloscope.

Special problems are met in the electrical testing of dual-coaxial balanced lines such as RG-23/U. Here problems of preparing lengths of cable which are electrically of the same length and which also show a high degree of electrical balance between the individual coaxials are often encountered. Fig. 7 shows a direct-reading electrical-length meter, developed by Federal Telephone and Radio Corporation, which operates on the principle that, at a fixed frequency, the input impedance of an open-circuited line is a function of the electrical length of the line. A voltage-regulated crystal-controlled generator applies a voltage to the input terminals of the line to be measured in series with a vacuum-tube radio-frequency milliammeter. The milliammeter is calibrated to read electrical length directly.

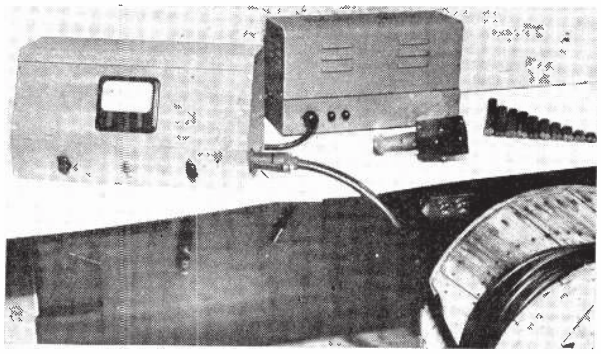


Fig. 7—Electrical-length meter.

To determine the electrical balance of dual-coaxial lines, particularly over a frequency range, a special balance test was developed. This set applies an equal voltage to both coaxials of the line from a motor-driven variable-frequency generator which slowly scans the frequency spectrum. At the far end of the line, a balanced-input amplifier operates a recording milliammeter to record the voltage unbalance.

A study of the graph recorded reveals the degree of unbalance and the frequency at which the greatest unbalance occurs. It will be seen that the development of test equipments has kept pace satisfactorily with the problems encountered in high-frequency transmission-line testing, although much work remains to be done to complete the picture. It will be appreciated that it is not possible at this stage to discuss other testing equipments which have been developed to meet special or specific problems, or to indicate the full extent of our knowledge, but the knowledge gained during this eventful period will be put to very good purpose in the years to come.

Future Outlook

A review of the current situation in the field of high-frequency solid-dielectric cables reveals the tremendous strides taken by a relatively inexperienced industry. The achievements of the past three years have been outstanding, but such successes must not prevent a critical examination of our present practices and theories, with an abandonment of those which fail to stand the test of scientific investigation. Certain fundamental weaknesses are already becoming apparent, and unless steps are taken to investigate these and to find solutions for them, what is now a virile section of the industry may stagnate and die, leaving other groups to find solutions to the problems along other lines.

In particular, continued research must take place into the field of dielectrics, with particular emphasis on the electrical characteristics and the operating temperature range. There are already many applications for transmission lines to operate at temperatures higher than 85 degrees centigrade, the present rating for polyethylene insulation, while the changes in characteristics observed over a temperature cycle due to the high coefficient of the thermal expansion of the same material are not very satisfactory. Braid designs, in view of recent work, can and should be modified to give the optimum mechanical and electrical properties.

One of the most important of the problems ahead is that of standardization. This must be considered not only from a national standpoint, but with an eye on international considerations, since we are now entering an era of widely expanded travel when equipments manufactured in one country will have to be serviced in another country. It will not be possible to uphold any nationalistic claims or demands in the face of a problem requiring over-all consideration, and the time is fast approaching when such problems must be tackled. A similar problem has been in the mind of industry for a number of years; namely, frequency allocation; and just as a series of conferences have been held on this subject, so must we have discussion and agreement on such problems as the impedance of cables, the maximum permissible attenuation at the various frequencies of operation, the over-all size of the cables and the connectors to be used therewith, etc. Without such standardization, the cable manufacturers will make whatever is called for by the customer and will have little inducement to study the problem deeply. The radio-equipment designer will continue to call for cables which may not constitute the best in the way of design, and the equipment installer and operator will go on decrying both. A vigorous discussion by all interested parties will clarify the position and enable the industry to go forward to even greater achievements.

The successful development of high-frequency solid-dielectric cables marks a very decided milestone in the history of radio, and it is up to the radio engineers to exploit more successfully the opportunity afforded them.

Acme Photo

HOTEL ASTOR—NEW YORK CITY
Headquarters for 1946 Winter Technical Meeting

1946 I.R.E. Winter Technical Meeting Program and Highlights January 23, 24, 25, and 26, 1946 Hotel Astor, New York, N. Y.

Final plans have now been completed for what is confidently expected to be the most important I.R.E. Winter Technical Meeting in many years. When members gather from January 23 to 26 at the Hotel Astor for this first postwar meeting, they will be treated to an array of features and events that are among the most significant ever prepared for such an occasion.

Amid the crowded calendar of professional and social events, members will have at this gathering an unprecedented opportunity to orientate themselves in the postwar pattern of the electronics and radio fields, to gain an understanding of the Industry's reconversion program, and to catch up on the newest developments, and future prospects in the field.

Space in the Radio Engineering Show, a display of unprecedented variety and importance and four times the size of any former I.R.E. Radio Engineering Show, has been fully spoken for by more than 132 firms.

The total of 171 exhibits occupying two floors and foyer space in the Hotel Astor will represent a comprehensive cross section of the Industry's newest and most important postwar products and should provide mem-

bers with much information of value and interest to them in their particular fields. The most recent list of the firms which expect to take part in the Show is given on page 42 W. The list indicates how completely the suppliers of radio engineering equipment and services are cooperating to make this year's Show an outstanding success.

The annual I.R.E. Banquet will be held Thursday, January 24, 7:30 to 10:30 P.M. in the Grand Ballroom of the Hotel Astor and the President's Luncheon, honoring the Institute's incoming president, Dr. Frederick B. Llewellyn, to be held on Friday, January 25, at 12:30 P.M. in the Grand Ballroom. The principal speakers will be Dr. Frank B. Jewett, President of the National Academy of Sciences who has accepted the invitation to address the estimated 2500 guests at the Banquet, and Mr. Edgar Kobak, President of the Mutual Broadcasting System, who will act as Toastmaster; Mr. Paul A. Porter, Chairman of the Federal Communications System, who will be the speaker at the President's luncheon, and Mr. Ronald J. Rockwell, Engineering Director, Broadcasting Division, The Crosley Corporation, who will be master of ceremonies at the Luncheon.

At Thursday evening's Banquet, the two annual I.R.E. awards will be made: The Institute Medal of Honor given in recognition of distinguished service in radio communications; and the Morris Liebmann Memorial Prize, made to a member of the Institute who has made public during the recent past an important contribution to radio communications. In addition, 12 fellowships given by the Institute will be awarded.

Another enjoyable feature, the annual Cocktail Party, to be held Friday evening from 6:30 to 8:00 P.M. in the Grand Ballroom, promises to provide a pleasant medium for the renewing of old acquaintanceships and the making of new social and business contacts.

The splendid array of important technical papers on vital electronics and radio subjects will this year take on added significance with discussion of the many remarkable war developments and newly released information on hitherto restricted items.

The subjects of the papers give some hint of their importance. They include: Military Applications of Electronics; Frequency-Modulation and Standard Broadcasting; Circuits and Theory; Television; Radio Navigation Aids; Vacuum Tubes; Microwave Vacuum Tubes; Antennas; Radar; Microwave Technique; Industrial Electronics; Communication Systems and Relay Links; Radio Propagation; Broadcast Receivers; Quartz Crystals; and Crystal Rectifiers.

This year, as has been announced, The Institute of Radio Engineers will be host at a joint meeting with the American Institute of Electrical Engineers, scheduled to be held in the Engineering Society's auditorium on Wednesday evening, January 23. Major General Leslie R. Groves, Director of the Manhattan District, which is the code name for the atomic-bomb project, will speak on "Some Electrical Engineering and General Aspects of the Atomic-Bomb Project. To accommodate any overflow attendance such as occurred last year, arrangements have been made to install a public-address system and to reserve another large meeting room in the same building.

The women guests at this Meeting will be entertained with visits to the Museum of Costume Art and Sloane's House of Years followed by luncheon and an art exhibition at the Town Hall Club, and a Television Tour of Radio City. They will also be escorted on tours through the Cathedral of St. John the Divine and Riverside Church, as well as guests at luncheon.

The complete program of events for the three-day Meeting follows.

Greystone-Stoller

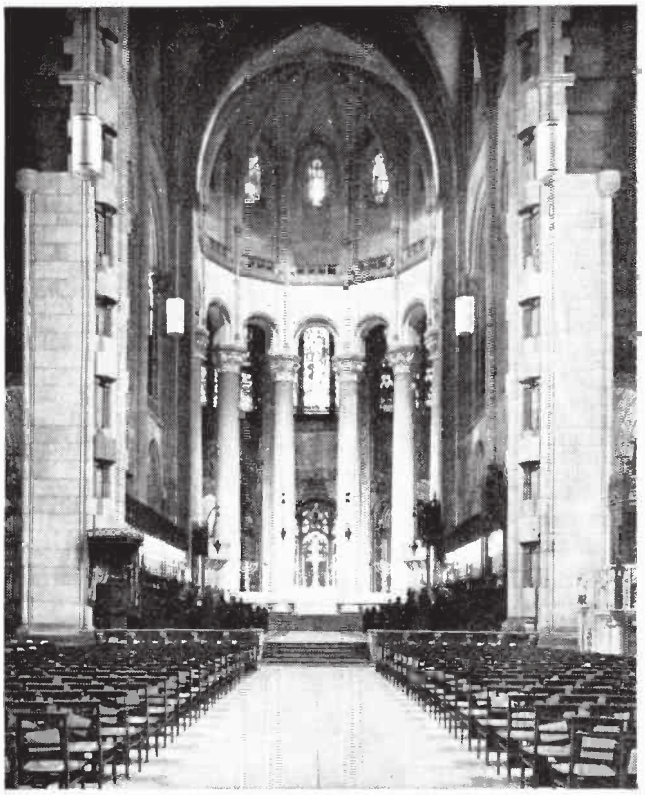
FRANK B. JEWETT

EDGAR KOBAK

PAUL PORTER

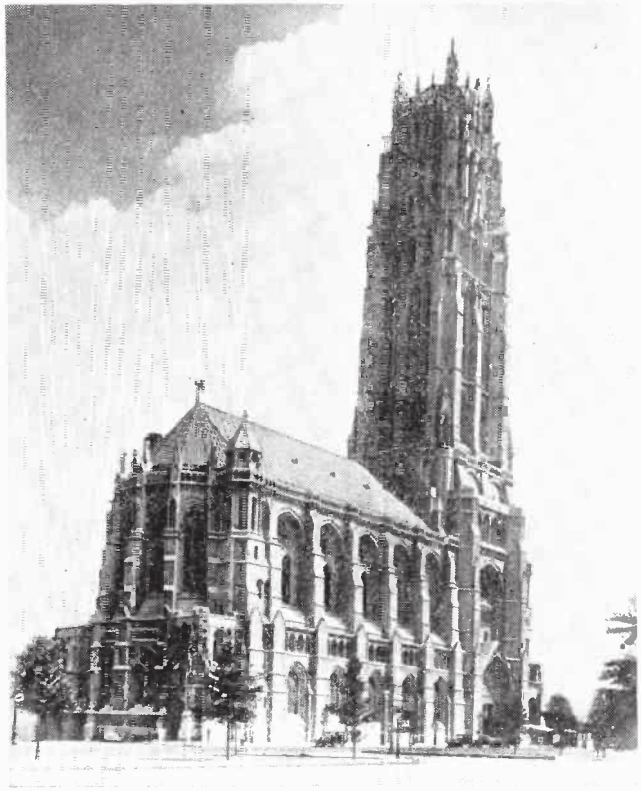
American

LEWIS M. CLEMENT



Gustafson

CATHEDRAL OF ST. JOHN THE DIVINE
Sanctuary and High Altar



RIVERSIDE CHURCH

Women's Program

(Tentative)

Thursday, January 24, 1946

11:00 A.M.–3:30 P.M.

Cathedral of St. John the Divine
Luncheon, Stoddards
Riverside Church

Friday, January 25, 1946

11:00 A.M.–4:00 P.M.

Museum of Costume Art—Sloane's House of Years
Luncheon and Art Exhibition, Town Hall Club
Television Tour of Radio City

FROM THE COLLECTION OF THE COSTUME INSTITUTE OF THE METROPOLITAN MUSEUM OF ART

PROGRAM

Wednesday, January 23, 1946

9:00 A.M.–5:30 P.M. Registration and Sale of Tickets
Promenade

9:30 A.M.–12:30 P.M. Annual Meeting of Sections' Representatives
Coral Room

12:30 P.M.–2:00 P.M. Luncheon for Sections' Representatives
Rose Room

2:00 P.M.–5:00 P.M. Annual Meeting of Sections' Representatives
Coral Room

4:00 P.M.–8:00 P.M. Radio Engineering Show
Eighth and Tenth Floors

8:00 P.M.–10:00 P.M. Joint Meeting of A.I.E.E. and I.R.E.
Engineering Societies Building

Thursday, January 24, 1946

8:30 A.M.–5:30 P.M. Registration and Sale of Tickets
Promenade

9:00 A.M.–7:00 P.M. Radio Engineering Show
Eighth and Tenth Floors

9:45 A.M.–10:30 A.M. Annual Meeting of The Institute of Radio Engineers, Inc.
Grand Ballroom

Technical Sessions

10:30 A.M.–12:30 P.M

Group A
Grand Ballroom
Military Applications of Electronics

Group C
Coral Room
Circuits and Theory

Group B
Rose Room
Frequency Modulation and Standard Broadcasting

Technical Sessions

2:00 P.M.–5:00 P.M.

Group A
Grand Ballroom
Television

Group C
Coral Room
Vacuum Tubes

Group B
Rose Room
Radio Navigation Aids

Thursday, January 24, 1946

Annual I.R.E. Banquet

Dress Optional

7:30 P.M.–10:30 P.M.
Grand Ballroom

Awarding of Medal of Honor, Morris Liebmann Memorial Prize, and Fellowship Awards
Address of Retiring President
Speaker: Dr. Frank B. Jewett, President of the National Academy of Sciences
Toastmaster: Mr. Edgar Kobak, President of the Mutual Broadcasting System, Inc.

Friday, January 25, 1946

9:00 A.M.–5:00 P.M. Registration and Sale of Tickets
Promenade

9:00 A.M.–10:00 P.M. Radio Engineering Show
Eighth and Tenth Floors

Technical Sessions

9:30 A.M.–12:00 NOON

Group A
Grand Ballroom
Microwave Vacuum Tubes

Group B
Rose Room
Antennas

Friday, January 25, 1946

President's Luncheon

Honoring President Frederick B. Llewellyn

12:30 P.M.
Grand Ballroom

Speaker: Mr. Paul Porter, Chairman, Federal Communications Commission
Master of Ceremonies: Mr. Ronald J. Rockwell, Engineering Director, Broadcasting Division, The Crosley Corporation

Friday, January 25, 1946

Technical Sessions

2:00 P.M.–5:30 P.M.

Group A
Grand Ballroom
Radar

Group C
Coral Room
Crystal Rectifiers

Group B
Rose Room
Microwave Technique

Friday, January 25, 1946

Cocktail Party

6:30 P.M.–8:00 P.M.
Grand Ballroom

Saturday, January 26, 1946

9:00 A.M.–3:00 P.M. Registration
Promenade

9:00 A.M.–2:00 P.M. Radio Engineering Show
Eighth and Tenth Floors

Technical Sessions

9:30 A.M.–12:00 NOON

Group A
Grand Ballroom
Industrial Electronics

Group C
Coral Room
Radio Propagation

Group B
Rose Room
Communication Systems and Relay Links

Radio Engineering Show—I.R.E. 1946 Winter Technical Meeting

Airadio, Inc.
Aircraft Marine Products, Inc.
Aircraft Radio Corporation
Aireon Manufacturing Corporation
Alden Products Company
Alpha Wire Corporation
Altec Lansing Corporation
American Brass Company
American Lava Corporation
American Phenolic Corporation
American Telephone and Telegraph Company
American Transformer Company
Amperex Electronic Corporation
Andrew Company

Ballantine Laboratories, Inc.
Alfred W. Barber Laboratories
Barker and Williamson
Bird Engineering Company
Boonton Radio Corporation
Brush Development Company
H. H. Buggie and Company
Burndy Engineering Company, Inc.

Allen D. Cardwell Manufacturing Corporation
Centralab, Division of Globe-Union, Inc.
Cherry Rivet Company
Sigmund Cohn and Company
Collins Radio Company
Communication Measurements Laboratory
Communication Products Company, Inc.
Communications
Condenser Products Company
Continental-Diamond Fibre Company
Cornell-Dubilier Electric Corporation
Corning Glass Works
Cornish Wire Company, Inc.
Crystal Research Laboratories, Inc.

Daven Company
DeMornay-Budd, Inc.
Tobe Deutschmann Corporation
Distillation Products, Inc.
John C. Dolph Company
Allen B. DuMont Laboratories, Inc.
DX Radio Products Company
Dynamic Air Engineering

Eastern Engineering Company
Eicor, Inc.
Eitel-McCullough, Inc.
Electrical Reactance Corporation
Electronic Laboratories, Inc.
Electronic Mechanics, Inc.
Electro-Voice, Inc.
Electronic Industries
Electronics
Erie Resistor Corporation

Fairchild Camera and Instrument Corporation
Fansteel Metallurgical Corporation
Federal Telephone and Radio Corporation
Ferris Instruments Company
F M and Television Magazine
A. W. Franklin Manufacturing Corporation

General Electric Company
General Electronics, Inc.
General Radio Company
Globe Wireless, Ltd.

Hallicrafters Company
Hammarlund Manufacturing Company, Inc.
Harco Tower, Inc.
Frederick Hart and Company, Inc.
Hewlett-Packard Company
Hytron Radio and Electronics Corporation

Industrial Instruments, Inc.
Industrial Products Company
Instrument Electronics
Instrument Specialities Company, Inc.
International Nickel Company, Inc.
International Resistance Company

J-B-T Instruments, Inc.
Jefferson-Travis Corporation
E. F. Johnson Company

Karp Metal Products Company, Inc.

Langevin Company, Inc.

Machlett Laboratories, Inc.
Madison Electrical Products Corporation
Maguire Industries, Inc.
Marion Electrical Instrument Company
Measurements Corporation
Mycalex Corporation of America

National Company, Inc.
National Research Corporation
National Union Radio Corporation
New York Transformer Company
North American Philips Company, Inc.

J. P. O'Donnell and Sons
Ohio Tool Company

Precision Tube Company
Presto Recording Corporation
Press Wireless, Inc.

Radio Corporation of America
Radio Craft
Radio Magazine
Radio News
Radio Receptor Company, Inc.
Raytheon Manufacturing Company
Rek-O-Kut Company
Remington-Rand Inc., Electronic Div.

Schweitzer Paper Company
Selenium Corporation of America
Shallcross Manufacturing Company
Sherron Electronics Company
Shure Brothers
Sola Electric Company
Solar Manufacturing Corporation
Sorensen and Company, Inc.
Sperry Gyroscope Company, Inc.
Sprague Electric Company
Stackpole Carbon Company
Standard Transformer Corporation
Star Expansion Products Company
Stupakoff Ceramic and Manufacturing Company
Superior Electric Company
Superior Tube Company
Sylvania Electric Products, Inc.

Telequip Radio Company
Television Magazine
Turney and Beale

U. S. Television Manufacturing Corporation
United Transformer Corporation

Ward Leonard Electric Company
Western Electric Company
Western Lithograph Company
Westinghouse Electric Corporation

Yardeny Engineering Company

Technical Sessions

2:00 P.M.–4:00 P.M.

Group A	Group B
Grand Ballroom	Rose Room
Broadcast Receivers	Quartz Crystals

Final Adjournment

4:00 P.M.

Committee Meetings

(Open to Members of Committees Only)

Wednesday, January 23, 1946

MORNING

Antennas	Radio Receivers
Frequency Modulation	Radio Wave Propagation

AFTERNOON

Circuits	Research
Membership	Television
Railway and Vehicular Communications	Vacuum Tubes

Thursday, January 24, 1946

MORNING

Education	Standards

AFTERNOON

Public Relations

Institute News and Radio Notes

Board of Directors

November 7 Meeting: At the regular meeting of the Board of Directors, which was held on November 7, 1945, the following were present: W. L. Everitt, president; G. W. Bailey, executive secretary; S. L. Bailey, W. L. Barrow, E. F. Carter, R. F. Guy, R. A. Heising, treasurer; Keith Henney, F. B. Llewellyn, Haraden Pratt, secretary; B. E. Shackelford, W. O. Swinyard, H. M. Turner, H. A. Wheeler, L. P. Wheeler, and W. C. White.

Approval of Executive Committee Actions: The actions of the Executive Committee taken at its October 3, 1945, meeting were unanimouly approved.

Annual Meeting of the Board: The Annual Meeting of the Board of Directors will be held on January 9, 1946.

Elections

The report of the Tellers Committee was accepted and the following nominees declared elected:

President—1946

F. B. Llewellyn

Vice-President—1946

E. M. Deloraine

Directors—1946–1948

W. R. G. Baker V. M. Graham

D. B. Sinclair

Committee

The following were selected as members of the Appointments Committee:

F. B. Llewellyn, *Chairman*

S. L. Bailey	L. C. F. Horle
W. L. Everitt	B. E. Shackelford
Keith Henney	D. B. Sinclair

Duplicate Publication of Papers: The Board of Directors established the following policy in connection with duplicate publication of papers:

"While in general it is the policy not to publish papers which have appeared elsewhere; nevertheless, in certain cases of outstanding importance, that policy shall not be considered obligatory."

Dr. Alfred N. Goldsmith: The Board extended expressions of sympathy in the illness of Dr. Goldsmith with best wishes for a speedy recovery and a return to his duties.

Browder J. Thompson

Memorial Fund: A check for $4000 for the Browder J. Thompson Memorial Fund was presented and an account of the status of the Memorial program outlined.

Award: The Browder J. Thompson Award was established in the manner and under the specifications outlined in the letter from Dr. R. R. Law to Mr. Pratt dated October 29, 1945, part of which is as follows:

"This award shall be known as the Browder J. Thompson Memorial Prize. Its purpose shall be to stimulate research in the field of radio and electronics and to provide incentive for the careful preparation of papers describing such research. The award shall be made annually to the author or joint authors under thirty years of age at date of submission of original manuscript (in case of joint authrship, all authors shall be under thirty years of age at date of submission of original manuscript) for that paper of sound merit recently published in the technical publications of The Institute of Radio Engineers which, in the opinion of the Awards Committee of the Institute, constitutes the best combination of technical contribution to the field of radio and electronics and presentation of the subject."

RTPB: It was unanimously approved that The Institute of Radio Engineers contribute toward the expenses of the Radio Technical Planning Board.

Co-operation and Liaison between I.R.E. and Foreign Societies: It was unanimously approved that the Board request the Executive Secretaries of the Institution of Electrical Engineers, London, England, and the Société Française des Radioelectriciens, Paris, France, to co-operate in publishing in the Proceedings of the I.R.E. and Waves and Electrons and both foreign publications statements inviting visitors from engineering societies abroad to get in touch with I.R.E., the British Society, and the Société Française, and that further co-operation between the societies and the I.R.E. be carried out.

Executive Committee

November 7 Meeting: The Executive Committee Meeting, held on November 7, 1945, was attended by W. L. Everitt, president; G. W. Bailey, executive secretary; S. L. Bailey, W. L. Barrow, E. F. Carter, R. A. Heising, treasurer; and Haraden Pratt, secretary.

Membership: Approval was given to the 371 applications for membership in the Institute as listed on page 38A of the December, 1945, issue of the Proceedings. These applications are as follows:

For Transfer to Senior Member Grade	25
For Admission to Senior Member Grade	12
For Transfer to Member Grade	76
For Admission to Member Grade	90
For Admission to Associate Grade	129
For Admission to Student Grade	39
	371

Editorial Department: Because of the temporary incapacity of the Editor to carry out his responsibilities, the Technical Editor, Mr. R. D. Rettenmeyer, was assigned to the special duty of Director of the Editorial Staff, reporting to the Executive Secretary.

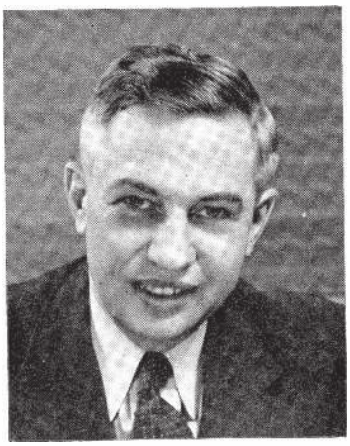
Yearbook: The Yearbook will be sold to nonmembers for $5.00.

Broadcast Engineering Conference: The Institute of Radio Engineers will continue cooperation with The Ohio State University and the University of Illinois and the National Association of Broadcasters in the Broadcast Engineering Conference which is to be held at the Ohio State University in Columbus, Ohio, during the week of March 18 to 23, 1946.

I.R.E.-RMA Committee: Raymond F. Guy, chairman of the Standards Committee, was invited as a representative of the I.R.E. to attend the meeting of the Executive Committee of the RMA Engineering Department which was held in Rochester on November 12, 1945. The recommendations of the I.R.E.-RMA Co-ordination Committee which was chiefly concerned with joint standards were accepted and approved.

Rochester Fall Meeting

Over one thousand registrants at the Rochester Fall Meeting, held on November 12 and 13, discussed their individual and industry problems and certain wartime and postwar developments. The Fall Meeting Committee awarded a plaque for distinguished service to Dr. Lee Du Bridge, director of the Radiation Laboratory, for the able manner in which he administered the vast National Defense Research Committee project which led to radar and our widespread and effective use of it during the war. At the banquet, Dr. Du Bridge outlined the capabilities and possibilities of the use of radar in a war-free world, especially in its service to navigational problems and to the safe flight landing of airplanes in all kinds of weather conditions.



Lee A. DuBridge

The following papers were delivered to capacity audiences of those in attendance at the 1945 Meeting:

"A Coaxial Modification of the Butterfly Circuit," by E. E. Gross of General Radio Company, contained considerable information on the mechanical problems arising in

constructing measuring equipment to operate in the thousand-megacycle regions.

"The Radio Proximity Fuze," by H. Trotter, Jr., of the Eastman Kodak Company, and "Proximity-Fuze Tubes," by Marcus A. Acheson of Sylvania Electric Products, Inc., not only disclosed a great deal of data on the use of these remarkable wartime devices but went to considerable length into the construction of the miniature tubes that made the fuzes possible.

"Microwave Radar," by Donald G. Fink of *Electronics*, brought engineers up to the minute on material that has been released for discussion. This included descriptions, including illustrations, of the apparatus for applying radar on frequencies as high as 10,000 megacycles and interesting facts about the actual usage to which radar was put during the war.

"High-Quality Sound Recording on Magnetic Wire," by L. C. Holmes of Stromberg-Carlson Company, gave those present a revelation of the advances that have been made in extending the frequency range and decreasing the distortion in wire recording. Demonstrations from RCA's new "unbreakable" vinylite records indicated not only the low record noise and wide dynamic range but also the fact that there is now very little difference between disk and wire recording, provided both are done correctly.

"The Aurora and Geomagnetism," by C. W. Gartlein of Cornell University, entertained the audience with many of the still unresolved perplexities of the aurora and of the effects of magnetic storms on communication. The lecture was illustrated with many photographs, including some in color, of aurora displays.

"Recent Developments on Converter Tubes," by W. A. Harris and R. F. Dunn of the Radio Corporation of America, discussed a new oscillator mixer good at 100 megacycles and above and thus applicable to the new frequency-modulation receivers. This tube has sufficiently high transconductance to be useful at the frequency indicated and sufficient conversion transconductance to operate at a 5- to 10-microvolt input level.

"War Influence on Acoustic Trends," by Hugh S. Knowles of the Jensen Radio Manufacturing Company, revealed much of the wartime usage of acoustic equipment and materials for morale (plus and minus), for training purposes, for getting speech and other forms of intelligence into and out of regions of high ambient-noise levels plus descriptions of "Bull" horns, "squawk" boxes, and other acoustic devices.

"Germanium Crystals," by Edward Cornelius of Sylvania Electric Products, Inc., gave many details of the wartime renaissance of crystal detectors indicating that the long-dormant crystal was henceforth a device to be reckoned with, due to modern engineering.

Television was treated by D. B. Smith of Philco Corporation in his paper "Industry Standardization Work in Television" and by E. W. Engstrom of the Radio Corporation of America who presented "A Review of the Technical Status." Under the title "Comments on Existing Television Systems from the Measurement Viewpoint," Jerry Minter of Measurements Corporation proposed that the carrier of the television system be amplitude-modulated for the picture and that the same carrier be frequency-modulated for sound; that receiver intermediate-frequency stages be matched to the transmitter characteristics resulting in overemphasis of the low-frequency video signals and that the high frequencies be brought up to match the low frequencies by "post-emphasis." These proposals evoked considerable discussion from the floor.

Not on the official program was a paper by C. W. Carnahan of the Zenith Radio Corporation giving the results of recent measurements on the comparative efficacy of the present frequency-modulation band and the new band (100 megacycles) at distances of 75 miles. A lively discussion over frequency-modulation allocations followed the presentation of the paper.

Joint Electron Tube Engineering Council

O. W. Pike (A'26–M'29–SM'43), chairman of the Joint Electron Tube Engineering Council, the newly formed agency of the National Electrical Manufacturers Association and the Radio Manufacturers Association, recently announced the complete organization of the Council which includes L. C. Hector (A'26–SM'43), A. Senauke (M'28–SM'43), G. R. Shaw (M'40–SM'43), and R. M. Wise (A'26–M'30–F'37). The Council approves standards before they are forwarded to NEMA and RMA and provides executive decisions as required. It also has the responsibility of guiding the seven committees established to deal with individual classes of tubes and the four committees established to co-ordinate such matters as sampling procedures, packaging, type designations, and mechanical standards.

Broad general policies and matters of financing the activities of JETEC are subject to approval of the Boards of RMA and NEMA handled by the directors of the Council who include W. R. G. Baker (A'19–F'28). Most of the work of JETEC during the past months has dealt with the needs of the Armed Services for the standardization of electron tubes necessary to the war. The Council, however, is primarily a peacetime organization and has been devoting some of its energy to postwar problems such as improved methods of defining tube types more accurately so that equipment may be designed with a better understanding of the problems of tube interchangeability.

Radio Industry's War Production

With a total war output of approximately 7½ billion dollars, the radio industry produced nearly twice as much radio-radar communications equipment during the war than it produced radio equipment alone for civilian use in all the years since commercial radio began about 1922. This was recently revealed by the Radio Manufacturers Association which has just received new production records of the War Production Board Radio and Radar Division.

From January, 1942, until the war ended last summer, the radio industry's war production mounted to the huge total of $7,220,000,000, the records show. In addition, the industry produced about $250,000,000 in military equipment from September, 1941, until the end of that year, according to the Radio Manufacturers Association, bringing the aggregate contribution to the war effort to close to the 7½ billion mark.

Best industry and trade statistics show that in the entire period of civilian radio beginning in 1922, the total volume of radio equipment manufactured was about $4,225,000,000, not including transmitting and communications equipment, the association announced. This is some 3¼ billion dollars less than the production total for war.

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Westman Amendment

The Westman Amendment, voting on an increase in membership dues, was passed by the members in August 1945.

Effective as of January 1, 1946, the new dues rate will be as follows:

Fellow	$10.00
Senior Member	10.00
Member	10.00
Associate	$10.00 and $7.00*
Student	3.00

* $7.00 for each year that is within the first five years of Associate membership, starting January 1, 1946. After five years the dues automatically shall be increased from $7.00 to $10.00. The five-year period is retroactive from January 1, 1946.

This constitutional amendment also discontinued the payment of all transfer fees and set the entrance fee at $3.00 for all membership grades with the exception of the Student grade which does not require an entrance fee.

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The Institution of Electrical Engineers (England)

The Institution of Electrical Engineers has offered I.R.E. members the privilege of subscribing for its named publications at the listed prices, which are half of the normal annual rates:

JOURNAL

Part I (General)	10s.6d. ($2)
Part II (Power Engineering)	15s.9d. ($3)
Part III (Radio and Communication Engineering)	10s.6d. ($3)
or	
all three Parts together	31s.6d. ($6) per annum.

SCIENCE ABSTRACTS

Section A (Physics Abstracts)	17s.6d. ($3.50)
Section B (Electrical Engineering Abstracts)	17s.6d. ($3.50)
or	
both Sections together	30s.0d. ($6)

A similar reduction (one half) on the PROCEEDINGS of the I.R.E. and WAVES AND ELECTRONS in case of the IEE members will result in the special rate of $6.00 a year (which includes $1.00 foreign postage).

I.R.E. People

NELSON P. CASE

NELSON P. CASE

Nelson P. Case (A'26–M'31–SM'43) has joined the staff of the Hallicrafters Company, Chicago Illinois, as chief engineer of the receiver division.

In 1924, Mr. Case was graduated from Stanford University with an A.B. degree in physics, and in 1926 he received an E.E. degree. He became active in geophysical work and held the position of assistant physicist at the Bureau of Standards, Washington, D. C., in 1928. The following year, Mr. Case was named research physicist in the department of engineering research at the University of Michigan. In 1930, he became a member of the staff of Hazeltine Electronics Corporation where he was engaged in various capacities for thirteen years, later having charge of the New York license laboratory of that organization. For the past two years, Mr. Case has been director of engineering design and development for the Hamilton Radio Corporation in New York City.

Mr. Case, holder of approximately thirty patents on radio-receiver circuits, is vice-chairman of the committee on broadcast and short-wave home receivers of the Radio Manufacturers Association's engineering department. He also serves on various other committees of this organization; namely, television receivers, systems, very-high-frequency receivers, and the executive committee of the engineering department's receiver section. Mr. Case is a member of Panel 6—Television Panel—of the Radio Technical Planning Board, a Fellow of the Radio Club of America, and a member of Phi Beta Kappa and Sigma Xi.

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E. FINLEY CARTER

E. Finley Carter (A'23–F'36) recently was elected a vice president in charge of industrial relations of Sylvania Electric Products, Inc. Previously he was chief radio engineer and later, as director of industrial relations he set up the company's industrial relations department. He will continue to be responsible for this function.

After he was graduated from Rice Institute in 1922, Mr. Carter joined the General Electric Company as a development engineer in the development of three early high-power transmitters, WGY in Schenectady, KGO in Oakland, and KOA in Denver. He was division engineer in charge of the special development division, handling television and the facsimile development program. In May, 1929, he became director of the engineering division of United Research Corporation, a subsidiary of Warner Pictures, designing radios, circuits, and receivers.

Mr. Carter was a director of The Institute of Radio Engineers in 1945 and is an Associate member of the American Institute of Electrical Engineers.

E. FINLEY CARTER

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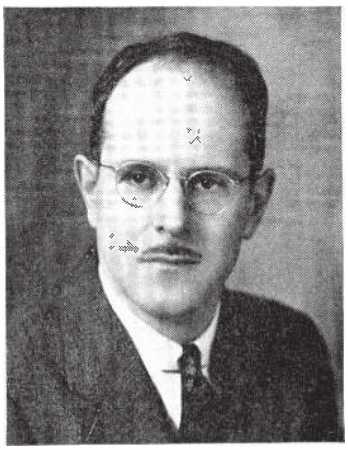
HERBERT J. REICH

Herbert J. Reich (A'26–M'41–SM'43), educator and author of scientific articles and textbooks, has been appointed professor of electrical engineering at Yale University, his work starting on January 1, 1946.

Dr. Reich was born on Staten Island, New York, on October 25, 1900. He received the M.E. degree from Cornell University in 1924, and the Ph.D. degree in physics in 1929. Since that time he has been on the staff of the University of Illinois, where he was professor of electrical engineering. On January 1, 1944, he was granted a leave of absence to join the staff of the radio research laboratory at Harvard University.

He has specialized in the field of electron tubes and electron-tube circuits, and has published approximately forty papers on these and related subjects in technical periodicals. He is author of "Theory and Applications of Electron Tubes," "Principles of Electron Tubes," and co-author of "Ultra-High-Frequency Techniques."

Professor Reich is a Senior Member of the Institute of Radio Engineers. He has served on the Board of Editors and several committees. During 1944, he was a Member of the Board of Directors of The Institute of Radio Engineers. He is a member of the American Institute of Electrical Engineers, the American Physical Society, the American Association for the Advancement of Science, and the Society for the Promotion of Engineering Education.



HERBERT J. REICH

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ROBERT J. GLEASON APPOINTED COMMUNICATIONS SUPERINTENDENT

Robert J. Gleason (A'31–M'39–SM'43) recently was appointed communications superintendent of the Pacific-Alaska Division, Pan American World Airways, with headquarters in San Francisco.

Mr. Gleason, who served with the U.S. Army since September, 1942, has been released from active service, in which he was a Lieutenant Colonel. During the past three years he served successively in Alaska, in the Aleutians, where he was in charge of all airways communications and was directly responsible for the installation of all radio communications in the Aleutian chain, in India and China, where since 1944 he was in charge of the 69th Army airways communications system and the 63rd AACS group in Kunming, China. These radio ground facilities served the 14th Air Forces under Major General Claire Chennault and the Indo-China Wing of the ATC. All "over the hump" flying between India and China was dependent on the Kunming communications center.

Originally joining Pan American in 1932, Mr. Gleason helped pioneer developments in Alaska first as chief operator in Fairbanks and later as communications superintendent for the company's operations throughout that area. He supervised the installation of communications facilities from Fairbanks to Juneau as well as fourteen of the radio stations throughout Alaska and Canada.

I.R.E. People

CLURE H. OWEN

CLURE H. OWEN

Clure H. Owen (A'32) joined the general engineering department of the American Broadcasting Company on October 1, 1945, as allocations engineer.

He will study allocations problems for standard-broadcast, frequency-modulation, and television facilities; be responsible for the design of directional-antenna systems; determine the location of suitable transmitter sites; and generally work towards the improvement of network coverage. He also will co-operate with the station relations department of the American Broadcasting Company in advising affiliates regarding allocation problems. Prior to joining the American Broadcasting Company, Mr. Owen was with the Federal Communications Commission as assistant chief of the broadcast-engineering division.

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LLOYD C. SIGMON

Major Lloyd C. Sigmon (A'29) has been appointed radio communications officer for the U. S. Group Control Council at Berlin. In recognition of his services in the European Theater of Operations, Major Sigmon was awarded the Legion of Merit Medal, and was made an honorary member of the French Signal Corps for his assistance to that organization. He has also recently been given the Order of the British Empire.

In prior years, Major Sigmon attended the school of electrical engineering, Milwaukee, Wisconsin, and from 1935 to 1940, was chief engineer for KCMO, Kansas City, Missouri. He then held the position of director of engineering for KMPC, Los Angeles, California, until his entry into the Armed Services as Captain in the U. S. Army Signal Corps in 1943. Shortly thereafter, he became chief radio engineer officer for communications in the European Theater. Before June of 1944, Major Sigmon selected the sites and directed the installation and operation of high-frequency and very-high-frequency radio stations in the United Kingdom for transatlantic and cross-channel communications in support of military operations on and after D Day. This included the planning for and implementation of the system which carried, throughout the world, the first news of the Allied invasion of the Continent.

Major Sigmon became engaged in the provision of radio communications facilities for Headquarters, European Theater of Operations, in Paris, where twelve high-power, high-frequency radio transmitting and receiving equipments were made operational within a month after that city's liberation. Upon completion of this project, he began the building of high-power mobile

LLOYD C. SIGMON

radioteletype stations to provide rapidly installed communications in support of the armies advancing in Germany. Among these is the 60-kilowatt, multichannel, suppressed-carrier, radioteletype, and radiotelephone station, whose equipment in actual operations was serviceable within twelve hours in Germany, providing the first army communications from that country to the United States.

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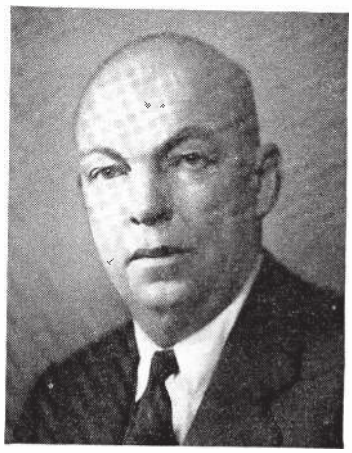
MAJOR ARMSTRONG TALKS ON FREQUENCY MODULATION

"Frequency Modulation is now coming into its rightful place in the communication field," said Major Edwin H. Armstrong (A'14–F'27) in an address delivered before the Cedar Rapids Section of The Institute of Radio Engineers on October 24.

Major Armstrong sketched the history of frequency modulation and compared it with amplitude modulation in regard to noise and distortion. Using charts to illustrate his talk, he said that noise and distortion are inherent in both the transmission and reception of amplitude-modulation signals, and that if pre-emphasis were used to



Bachrach

EDWIN H. ARMSTRONG

bring up the high audio response, distortion in amplitude-modulation is aggravated. He pointed out that the use of "exalted carrier" in an amplitude-modulation receiver greatly improves the quality of reception.

"Distortion due to multipath transmission is practically nonexistent in frequency modulation," said Armstrong. He recounted his extensive investigation into that phenomenon, and his conclusion that multipath transmission would cause distortion only in mountainous country, and then only in extremely small areas.

The Major predicted that an 80-mile radius could be served from one frequency-modulation station without the aid of booster transmitters. The variety of programs transmitted and the number of different stations required for a given locality will be about the same as the existing amplitude-modulation service.

The frequency-modulation receivers will have to be of very high quality and will be relatively expensive if they are to be capable of reproducing frequency-modulation transmissions with the high quality that is possible with frequency-modulation.

Discussing the inception of frequency modulation, Major Armstrong said that he started looking for a static eliminator back about 1914, and that he worked a little longer than most people did. He then hit upon the idea of frequency shift-keying, and from that went into frequency modulation.

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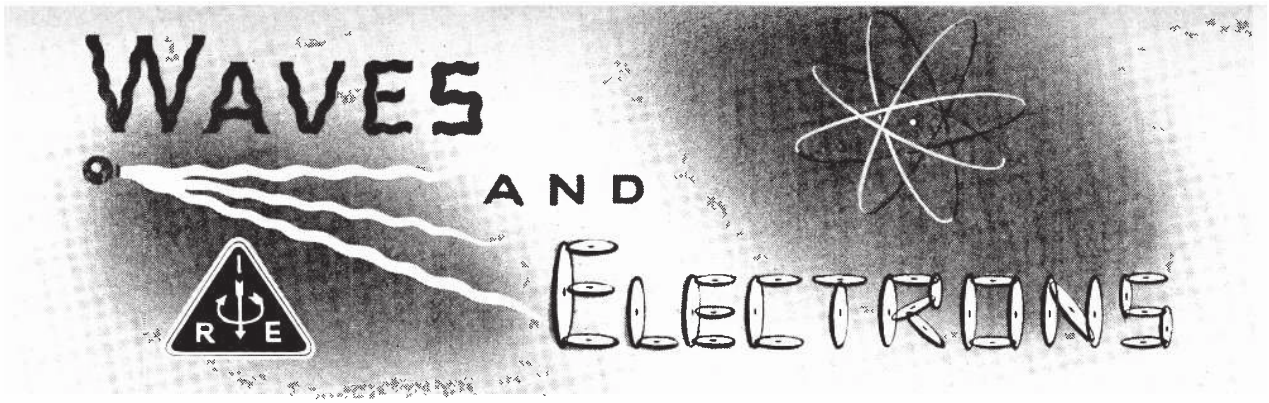
JOHN J. GUARRERA

John J. Guarrera (S'42–A'44), formerly a staff member of the Radiation Laboratory, Massachusetts Institute of Technology, is now affiliated with the engineering staff of Bernard Rice's Sons, Inc., New York, which during the war produced a wide range of electronic devices. It will continue to develop, engineer, and manufacture in the microwave, ultra-high-frequency, and radio-frequency fields.



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Donald B. Sinclair

Board of Directors—1946

Donald B. Sinclair was born at Winnipeg, Manitoba, Canada, on May 23, 1910. He attended the University of Manitoba from 1926 to 1929, and from 1929 to 1932 was enrolled in a co-operative course in electrical engineering at the Massachusetts Institute of Technology, from which he received the S.B. degree in 1931, the S.M. degree in 1932, and the Sc.D. degree in 1935.

During 1930 and 1931, Dr. Sinclair was associated with the Bell Telephone Laboratories and the New York Telephone Company, in New York City, and with the Western Electric Company, in Hawthorne, New Jersey. As a research assistant, from 1932 to 1935, and research associate during 1935 and 1936, he worked with the Massachusetts Institute of Technology on the electrocardiograph, electromechanical computing machines (differential analyzer and cinema integraph), and high-frequency measurements. Under co-operative arrangement with the General Radio Company, his doctorate research work on high-frequency impedance measurements was sponsored by that organization and done in its laboratories during 1934 and 1935.

In 1936 Dr. Sinclair became an engineer with the General Radio Company, and was appointed chief engineer in 1944. His work in this connection has dealt with general development and design of measuring instruments, with emphasis on high-frequency impedance-measuring equipment.

Dr. Sinclair was a radio amateur in Winnipeg from 1926 to 1929, under call VE4FV, and from 1928 to 1929 he was a part-time radio operator for the Western Canada Airways. His wartime activities include work as research associate and consultant with the radio research laboratory of Harvard University, and as a section member on the National Defense Research Committee. He served in North Africa at the Allied Force Headquarters in 1943, as technical observer with the United States Army Airforces.

Dr. Sinclair became a Junior member of The Institute of Radio Engineers in 1930, an Associate in 1933, a Member in 1938, and a Senior Member in 1943. He was awarded the grade of Fellow in 1944, "for the development and application of various types of networks for high-frequency measurement of impedance." He was elected a member of the Board of Directors of the Institute in 1945, and is active on the Papers, Papers Procurement, Television, and the Antenna Committees. He also served on the Transmitters and Antennas Committee from 1941 to 1944.

The New York Section of the Institute held its fourth Radio Pioneers' Dinner on November 8, 1945. Two of the honored guests, Rear Admiral Joseph R. Redman, U. S. Navy, Chief of Naval Communications, and Major General H. C. Ingles, Chief Signal Officer, War Department, addressed to Louis G. Pacent, Chairman of the General Committee for the dinner, the tributes to all radio and electronic engineers and workers which are presented below.

Army and Navy Letters of Recognition

On the occasion of your Radio Pioneers' Party, I welcome the opportunity to express the gratitude of the Signal Corps to the many radio-and-electronic engineers whose notable contributions to victory are now part of an imperishable historical record.

Demands, undreamed of by the founders of radio, were made by the Signal Corps upon those engineers and upon the entire electronics industry.

These demands were met even though it was necessary to create what virtually amounted to a new industry. Organizations and individuals placed the war needs of the nation above all other considerations and in the quality and quantity of their production and by their unselfish public service earned the acclaim of their country.

It is the earnest desire and confident hope of the Signal Corps that this close relationship and co-operation will not now be relaxed but will continue long into the future in order that our Army may be assured of unparalleled communications equipment.

Sincerely yours,
H. C. Ingles
Major General
Chief Signal Officer

Whenever a group of old-timers meet at a gathering such as this Radio Pioneers' Party it is customary to think back over the years and to reminisce about the progress that has been made within our field. It is doubtful that the most imaginative old-timer could predict the remarkable development which was to take place in radio. Both World Wars I and II proved to be a tremendous stimulus to the radio industry. The great strides we have made in electronics during the past few years are now beginning to be made known to the public. The result will be that the electronic industry will step up in importance to one of the front-rank fields of our daily life and will find outlets for its devices in every branch of human endeavor.

Our national defense will depend to a still greater extent upon the electronic devices in the near future. It is an important element in all our planning. Our position in world affairs is dependent upon the progress which we have made and hope to make in the future. The progress we make will be the result of the brain power and human efforts which lie behind all development work. The past history is remarkable but we may be certain that the future will be even more so. The Navy appreciates the good work which has been done and will co-operate in every way in order to assist in making future developments as fantastic to the present-day conceptions as is the present state compared with the crude wireless you pioneers experimented with in the early days.

The Navy extends its congratulations to the Pioneers who laid the ground work for the achievements of the present day. 73.

Joseph R. Redman
Rear Admiral, U.S. Navy
Chief of Naval Communications

The Historical Background of the Canadian Council of The Institute of Radio Engineers*

RALPH A. HACKBUSCH†, FELLOW, I.R.E.

WHILE the actual inception of the Canadian Council of The Institute of Radio Engineers is relatively recent, the events leading up to the formation of the Council date back to the year 1925.

During that year, a group of radio engineers in Toronto decided that they should set up a group representative of the radio engineers in Canada, and after mature discussion, petitioned the Board of Directors of The Institute of Radio Engineers for a charter setting up a Canadian Section on October 2, 1925.

This charter was granted on July 10, 1926, and the Canadian Section, as such, made considerable progress, partially due to the energetic leadership of the various executive committees, partially to the fact that Toronto became the center of the bulk of receiving-set manufacture in Canada prior to 1931, and partially to the fact that the University of Toronto offered a communications option in the electrical-engineering course of the School of Practical Science, dating back to 1922.

The fact that the Dean of the department of electrical engineering, several of the professors, and many of the lecturers at the university were interested in the work of the Institute, and the fact that the meetings have always taken place in the Electrical Building of the university, have contributed to the progress of the Institute in the Toronto area.

In August, 1930, due to the energetic work of the Toronto group, the Fifth Annual and First International Convention of the Institute took place in Toronto, during which convention joint meetings with the engineering committee of the Radio Manufacturers Association were featured, following a pattern instituted in the United States of America at the Radio Manufacturers Association Annual Meeting at Atlantic City the previous year.

The Canadian Section co-operated with the Rochester, Buffalo, Niagara Falls, and Cleveland Sections in establishing the successful I.R.E. Eastern Great Lakes District Convention, held in Rochester in the fall of 1929, which was the forerunner of the now annual Rochester Fall Meeting of members of the I.R.E. and of the Radio Manufacturers Association engineering department.

After the depression of 1930, many of the receiving-set manufacturers in the Toronto Area ceased to function, and many of the engineers who had been charter members of the Canadian Section of The Institute of Radio Engineers moved to Montreal, which was the center of the commercial activities of three large companies.

It was natural that this group should petition the Institute's Board of Directors for a charter for a Montreal section. This charter was granted on December 2, 1936, and formally presented to the Section on January 20, 1937.

Due to the close co-ordination of the members of the Montreal Section and the Toronto Section through close association in the activities of the Radio Manufacturers Association of Canada engineering committee over a period of years, the Canadian members of the Institute were kept informed of the activities of the two Sections.

With the advent of the war, Canada having declared war on Germany in September, 1939, there started a displacement of personnel from former centers and an increased interest in the field of radio and electronics. Naturally, there followed an increase in the Canadian membership of the Institute and a specific localization of interest in those areas where the war effort had established centers of activity.

There followed in rapid succession the formation of a Section in Ottawa, Canada, chartered September 5, 1944, and a Section in London, Ontario, chartered on November 24, 1944.

During this period the Canadian Government had passed certain labor laws dealing with collective bargaining, which affected professional engineers and those members of the Institute resident in Canada, who held a professional status and/or held membership in one or more of the Provincial associations of professional engineers, which had been established by Provincial law—Quebec, 1909; Ontario, 1922.

In order to meet this situation, a committee representative of the four major technical societies or bodies in Canada, set up a Committee of Fourteen to meet with the Government to discuss the professional phases of the Federal labor laws. However, prior to this, a representative of the Montreal Section had proposed that the Toronto and Montreal Sections should set up a Council to deal with such problems. Such councils or regional representation having been proposed by ballot to the

* Decimal classification: R060. Original manuscript received by the Institute, October 3, 1945.

† Stromberg-Carlson Company, Toronto, Ontario, Canada.

membership during 1941, but unfortunately defeated.

In view of the fact that the situation in Canada was unique and because of the fact that the writer was the vice-president of the Institute, and a member of its Board of Directors at the time when these problems became apparent, a request was made to the Board to permit the writer to act for the members of the Institute during this interim period, in collaboration with other engineering societies, in protecting the rights of our members in Canada, in connection with government acts and regulations.

At the same time, recognizing the fact that the members of the Institute resident in Canada were subject to the laws of the Government of Canada and various Provincial acts, the writer placed a motion before the Board of Directors to permit the functioning of national councils on an interim plan of action, which would not involve the Institute financially or legally, to deal with national matters within any one country until such a time as the Board of Directors decide on a final policy, and suggested that the chairmen of the Sections involved should act to give effect to this motion.

The I.R.E. Board of Directors unanimously passed this motion September 6, 1944, but it was not until April 7, 1945, at London, Ontario, that the chairmen met formally to set up a Canadian Council of The Institute of Radio Engineers.

At this meeting, it was agreed that the Council should consist of the chairman of each Section, the immediate past chairman of each Section (as ex-officio members), and to ensure close contact with Headquarters in New York, any Canadian Director of the I.R.E. who is resident in Canada. In the event that no Canadian, resident in Canada, be elected or appointed to the Board, it is further moved that a quorum of the Council be empowered to nominate for membership on the Council a representative for the Canadian membership at large.

It was agreed that the Secretary of the Council should be the chairman or the immediate past chairman of the Section from which the elected chairman of the Council had come, thus ensuring an effective working relationship between these two officers of the Council. The objects of the Council are those set forth in the constitution of The Institute of Radio Engineers, Article 1, Section 2; namely,

(a) Its object shall be the advancement of the theory and practice of radio and allied branches of engineering and of the related arts and sciences, their application to human needs, and the maintenance of a high professional standing among its members.

(b) The Council shall act for the Canadian membership of the Institute on Canadian matters which are the common concern of the Canadian members, but it shall not involve The Institute of Radio Engineers either financially or legally.

(c) The Council shall endeavour to correlate the thoughts and actions of the Canadian membership of the Institute so that it may express the opinions of all Canadian members.

(d) The Council shall consider and take appropriate action in the following: (1) legislative matters affecting the Canadian membership and which are peculiar to Canada; (2) matters which require joint action with other engineering and professional associations in Canada; (3) matters associated with the education of professional workers in the fields of radio, communications and electronics; (4) matters associated with the professional status of workers in these fields; (5) matters associated with the public recognition of the contribution made by the radio and electronic industries in Canada during the war years; (6) such other matters as shall be added by a majority vote of the Council.

(e) The Council shall, at the request of the Sections, serve as a clearinghouse for speakers and papers and in a like capacity in other matters which may arise from time to time.

At the first meeting Dr. F. S. Howes, of the Montreal Section, was named chairman, while E. O. Swan was named vice-chairman. Since this date, L. A. W. East, the chairman of the Montreal Section, was named the secretary, and various committees were established under instructions from Chairman Howes, covering professional status, education committee, and a Canadian charter committee.

The Canadian Council of The Institute of Radio Engineers is a contributing sponsor to the work of the Canadian Radio Technical Planning Board, and maintains membership in the Canadian Council of Professional Engineers and Scientists.

At the present time, the expenses of the Council are defrayed by special vote of the Board of Directors.

It is felt that the work of the Canadian Council will establish a pattern for other groups within the Institute residing outside of the United States, to perform similar functions for their members, and thus further the usefulness and standing of a truly international Institute of Radio Engineers.

A Plea for the Scientific Method*

LOUIS HOFFER†

Summary—**The rapid growth and development of the radio industry accelerated by the impetus of war, the new technical advancements, and the increased complexity of electronic application have indicated the need for more intensive training and a revision of the educational approach in this field.**

Too much emphasis cannot be given to the inculcation of the "scientific habit of thought" and the development of the "scientific research" method in engineering thinking.

What is Scientific Research

SCIENTIFIC research is a method of finding out what we want to know, a technique which has survived because of its utility. The test of the validity of any method lies in its results. Whatever technique achieves that result is necessarily a valid technique. These techniques may vary from the "trial-and-error" method of the simple technician to the rigorous solution of a highly complicated abstract mathematical problem by a professional. The method to be adopted should be the one which is direct, simple, accurate, and reliable.

It is understood that all methods are tentative. Everyone works out something for his own use. Even in the highly formalized sciences, new methods supplant old. Methods in vogue in any field are the residues of techniques used by men to find out what they wanted to know.

However, one method man has used has enabled him to attain an understanding and control of the physical world far beyond the fondest dream of the ancients. In view of the success of this method, the scientific technique, we should be interested in its application to radio engineering. Conscious effort should be made to train the engineer in the common characteristics of this technique.

Critical Discrimination

The first requisite of this method of scientific analysis is the determination and ability to get at the basic facts and not be influenced by mere appearance, prevalent notions, and one's own wishes. Such a mental attitude is the core of the scientific frame of mind. It is the "be all" of all science.

Perhaps the best account of a scientific frame of mind is to be found in Francis Bacon's flattering description of *himself* in one of his famous works: "A mind nimble and versatile enough to catch the similarity between facts, and at the same time, steady enough to fix and distinguish their subtle differences, . . . endowed by nature with the desire to seek, the patience to doubt, fondness to meditate, slowness to assert, readiness to consider, carefulness to dispose and set in order, neither affecting what is new nor admiring what is old . . . "

Critical discrimination is indispensable in all fields and is really a prime requisite in the field of engineering research. The radio industry would profit immeasureably from the scientific frame of mind on the part of every investigation in the laboratory.

Classification

A second requirement of the scientific method is proper classification. Once the data have been collected by observation and experimentation, it is necessary to recognize the relationships that exist between these collected facts. Electrical phenomena should be classified on the basis of the similarity of the character of things, processes, and results achieved.

These classifications may be natural ones, such as the classifications of chemical elements based on atomic weights; or special-purpose classifications for specific objectives. The point is that, in order to arrive at proper conclusions, data must be arranged in some orderly array which naturally leads to such conclusions.

Of course, there is always the danger of improper classification for special purpose. The story is told of that lady who went on a railroad journey with a menagerie of pets. The conductor informed her of the fare for her dogs but didn't know the charge for her other pets. After inquiry of the railroad office, the conductor told the lady that according to the office, "as cats are dogs and rabbits are dogs and so are parrots, the fare would be the same but this here tortoise is an insect so there isn't any charge for it." So far as the railroad was concerned dogs, cats, and parrots belong to the same class, but it would be dangerous to use that type of special-purpose classification in the field of engineering research.

Fair Sample and Verification

Our scientific method starting from observed fact and experimentation usually ends in generalizations of some kind concerning large classes and groups of facts. The right we have to apply the results of our observations of a very limited number of facts to a large number of others which have not been observed depends on the principle of fair sample and verification, which means

* Decimal classification: R070. Original manuscript received by the Institute, October 9, 1945.

† Emerson Radio and Phonograph Corporation, 111 Eighth Avenue, New York 11, N. Y.

that, with reasonable care, it is possible to judge the character of a large group by the aid of a sample selection from it.

Science, in this, as in other respects, follows the lead of the practical man. In business, it is often impossible to examine each item in a large shipment of goods. Hence, businessmen are content to estimate the character of the whole shipment by the aid of a sample. On the whole, experience shows that, provided the sample is selected with some care, it fairly represents the whole, but is itself only a small fraction of the whole. The actual number of samples is less important than the range of selection, and the accuracy of the generalization depends not only on the proper selection but on the degree of accuracy achieved in verifying the conclusion.

Importance of Scientific Technique

Too often only lip service has been paid to the "scientific habit of thought" summarized in the preceding paragraphs. Little effort is made to define the problem and determine the most fruitful line of attack. The game of prodigal waste called "tinkeritis" seems to have a tremendous appeal as an occupational technique, even though the dangers of illusion, fallacy, and "wish fulfillment" are common and serious enough to warn any sensible person who uses the critical approach against excessive confidence in his own conclusions without verification. As a matter of fact, there appears to be a large number of workers in the radio-engineering field who take pride in their ignorance of scientific techniques of logic, and of the value of the faculty of critical discrimination. To them, scientific technique and logical analysis are a kind of refined intellectual game played according to certain rules in selected academic circles.

In reality, however, the scientific method is as important and serious as life itself. Pursued in the right spirit, it will not only lead to the enrichment of engineering research, but will also be an invaluable training in the art of self-criticism which is so necessary to the peace and welfare of humanity.

Need for Pure Research

Scientific research and the scientific frame of mind are handmaidens of pure science. Not only is there a need for the scientific technique in radio engineering, but also a need for fundamental inquiry into basic principles. If only the practical and useful aspects of radio engineering are considered, the radio industry will soon find itself "intellectually handcuffed" and in exactly the same position as that of the manufacturer who suddenly finds himself cut off from his supply of raw materials from which he fabricates his finished product.

As one writer has said, "Everyone recognizes that applied science rests on pure science—that, to cite a single illustration, radio communication would have remained not only impossible but inconceivable save for the fundamental experiments of Faraday, the mathematical formulation of wave theory by Maxwell, the experimental realization of Maxwell's predictions by Hertz—all being advances in knowledge made without thought of practical application or financial return."

"All the ingenuity in the world could not have produced an automobile until science had brought to light the electrical, metallurgical, and mechanical principles involved in its construction."

However, there appears to be a lack of appreciation of the importance and the possibilities of pure research. If insufficient attention and inadequate financing of pure research continues, the stream of creative thought in the field of radio engineering will eventually dry up.

If the Radiation Laboratory at The Massachusetts Institute of Technology (Office of Scientific Research and Development) had such admirable success in war, intelligent industry should see to it that its research role is continued in peace. Industry could certainly develop "a moral-equivalent-of-war spirit" to subsidize a permanent "radiation laboratory" or other research body, devoted to pure science and beneficial to both industry and society.

As Admiral S. C. Hooper said in the June, 1943, issue of the Proceedings of the I.R.E., "The progress and prosperity of our Nation, as well as the readiness of its forces of war, are in no small measure dependent upon keeping peacetime research going full speed."

Radio-Frequency Dehydration of Penicillin Solution*

GEORGE H. BROWN†, FELLOW, I.R.E., R. A. BIERWIRTH‡, MEMBER, I.R.E., AND CYRIL N. HOYLER†, SENIOR MEMBER, I.R.E.

Summary—Many pharmaceutical materials, such as penicillin and antitoxins, lose their desirable properties when the material is in liquid solution for a period of time. In general, these solutions suffer from the application of heat. In the dry state, the same materials retain their properties over long periods of time, even at elevated temperatures. Drying of penicillin is generally carried out by freezing and then applying a high vacuum so that the material is dried by sublimation. This paper describes certain experiments and developments made by the authors to bring about the drying of penicillin by the application of radio-frequency power in a very moderate vacuum.

The system presented in this paper has been divided into three parts: (1) bulk concentrating of the solution; (2) drying the concentrate in the final containers to a moisture content of a few per cent; and (3) completing the drying in auxiliary chambers. The equipment is capable of producing 2000 dry bottles per hour, using inexpensive vacuum pumps and simple condensers. The whole system operates with a minimum of maintenance.

A few experiments have been made concerning the drying of other pharmaceuticals with promising results.

I. Introduction

LATE IN 1943, many newspaper and magazine articles were published which told the story of the manufacture of penicillin. Particular emphasis was given to the problem of drying the product for packaging. Two points were stressed. First, penicillin in a water solution soon lost its bactericidal properties so it was necessary to dry the product thoroughly before storage or shipment. Second, penicillin solution was so sensitive to heat that it was necessary to keep the solution in a frozen condition before drying and even to dry in the frozen state.This freeze-drying process was expensive and took a long time. Our previous work in dehydration of materials by means of radio-frequency power, particularly the drying of rayon cakes in a vacuum, led us to speculate about the possibilities of contributing something to the penicillin production program by the application of radio-frequency power. The writers then suggested to the late Dr. George A. Harrop, Director of Squibb Biological Laboratories, that it might be possible to evaporate the water from the liquid state if the vacuum were such that the boiling point remained at about 50 degrees Fahrenheit and the energy necessary for vaporization were supplied by a radio-frequency generator. Dr. Harrop expressed great interest in the possibilities and offered to co-operate in tests to determine whether such a procedure would harm the product. Before such tests could be made, other producers of penicillin heard of our ideas and wished to discuss the proposal. Some of these producers provided samples for test purposes. A description of the pertinent tests will be included in this paper. In order to orient the reader, it seems desirable to say a few words concerning the methods of testing for bactericidal properties and the means of expressing these properties, since the purpose of our early experiments was to determine how our radio-frequency methods affected these properties.

* Decimal classification: R590. Original manuscript received by the Institute, September 18, 1945.

† RCA Laboratories, Princeton, N. J.

‡ Formerly RCA Laboratories, Princeton, N. J., now Sound, Inc., Chicago, Ill.

II. Penicillin Activity or Potency

Pure crystals of penicillin salt are believed to be very stable and to have constant bacteria-destroying properties for a given weight. Pure crystals are difficult to obtain. However, in limited amounts, these crystals are useful in testing solutions of penicillin which contain impurities and are of unknown activity. The Oxford unit of activity was selected shortly after the discovery of penicillin, so the unit is smaller than necessary for convenient use.[1] Pure crystals of penicillin possess 1667 Oxford units of activity per milligram.

In testing a solution of unknown potency, various dilutions of the substance are placed on a bacteria culture. At other spots on the same plate, a penicillin solution of known activity is placed. After incubation for a fixed period of time, observations are made of the dimensions of the zones of inhibition.

Another test makes use of observations of turbidity of various dilutions of penicillin in cultures of bacteria. Again the observations are correlated with a known solution.

The accuracy or consistency of these bacteriological determinations is not very great. A number of measurements of potency taken on the same sample may show deviations as high as plus or minus fifteen per cent from the average.

In our experiments, control samples were kept so that any deterioration of the solution with time could be sorted out from the effect of radio frequency.

III. Initial Experiments with Radio-Frequency Heating

With a few exceptions, the people connected with penicillin production assured us that it was extremely important to keep the solution frozen throughout the drying cycle. They warned that if this were not done the potency would be lost. The statements did not appear to be based on experience related to the method of

[1] One Oxford unit is that amount of penicillin which, when dissolved in 50 milliliters of meat-extract broth, just inhibits completely the growth of the test strain of *Staphylococcus aureus*.

drying which we proposed. Therefore, it seemed desirable to determine by experiment just what the effect would be.

To dry by conventional freeze-drying methods,[2] it is necessary to maintain a vacuum of between 100 and 300 microns (0.1 to 0.3 millimeters of mercury). We were not interested in freeze-drying with radio-frequency power, for a number of reasons. In the first place, if we were to contribute to the penicillin program by furnishing a faster and simpler system, the elimination of the expensive high-vacuum systems, complicated condensers, and elaborate refrigeration seemed to be the most important step. Second, for the same voltage or electric intensity, the residual atmosphere ionizes much more readily with a vacuum of 100 microns than it does at a vacuum of about 20 millimeters, which is the order of vacuum that we had in mind for our purpose. In addition to the fact that the air ionizes easier at 100 microns, the solution is frozen when under this vacuum. The electrical conductivity of frozen penicillin is so much lower than that of the liquid that much higher voltages must be used to generate the same power. This effect is very pronounced. When attempts were made to dry in the frozen state with radio-frequency power, it was necessary to reduce the radio-frequency voltages to such an extent that it became apparent that most of the heat of vaporization was being supplied by heat conduction from the warm air of the laboratory through the glass walls of the container.

A number of samples of a weak solution of penicillin were submitted by the representatives of a penicillin producer. They were anxious that the tests be made in the frozen state, so only one sample was subjected to the test which we wished to make. Each sample was a frozen solution weighing 1000 milligrams. The results of the experiments are given in Table I.

TABLE I

Sample	Final Weight (Milligrams)	Units of Activity Per Milligram	Total Units In Sample	Treatment
Control	58.7	67.0	3933.0	Control dried by conventional freeze-drying.
1	59.1	47.0	2780.0	Shelled[1] and dried for 80 minutes with radio frequency, vacuum of 80 microns.
2	68.4	55.0	3760.0	Shelled[1] and dried for 60 minutes with radio frequency, vacuum of 100 microns.
3	57.5	76.0	4370.0	Not shelled. Radio frequency applied for 10 minutes, but vacuum of 100 microns for 90 minutes.
4	55.5	82.0	4550.0	Frozen when placed on pump, and vacuum of 10 millimeters applied. Radio-frequency power used. Melted immediately. Appeared dry in five minutes. Heating continued for total of 30 minutes.

[1] Shelling is the procedure of freezing the liquid in a thin layer on the sides of the bottle, accomplished by holding the bottle on its side and slowly rotating the bottle while submerged in a refrigerant until the contents are completely frozen.

The tests shown in Table I indicated that the best results were achieved by boiling out the water at the relatively high pressure of 10 millimeters. Since this was not in accordance with the opinion of experts, it seemed desirable to verify this conclusion by further tests. Accordingly, four samples obtained from E. R. Squibb and Sons were treated. These samples were all frozen when placed in the drying apparatus. However, the pressures were high enough so that the material quickly melted. The following conditions prevailed for these samples:

Sample 1: Vacuum of 10 millimeters. Drying time 52 minutes.

Sample 2: Vacuum of 18 millimeters. Drying time 103 minutes.

Sample 3: Vacuum of 6 millimeters. Drying time 75 minutes.

Sample 4: Vacuum of 3 millimeters. Drying time 35 minutes.

The activity tests reported by Squibb Laboratories were as shown in Tables II and III.

TABLE II

	Control No. 1	Control No. 2
First dilution	73,100 units	82,400 units
Second dilution	70,900 units	82,500 units
Average	72,000 units	82,450 units
Average of controls	77,225 units	

TABLE III

Sample	First Dilution	Second Dilution	Average
1	82,400	76,200	79,300
2	83,560	82,100	82,830
3	76,100	77,500	76,800
4	75,000	72,700	73,850
Average of radio-frequency samples			78,195

Four more samples were later dried under the following conditions and tested for activity by Squibb Laboratories (Table IV).

TABLE IV

Sample	Activity	Treatment
5	88,644	Vacuum of 150 microns, with radio frequency. Sample frozen throughout treatment. Drying time 5 hours.
6	87,316	Vacuum of 10 millimeters. Drying time 70 minutes. No loss of weight after 40 minutes. Sample melted quickly and had dried appearance after six minutes.
7	83,664	Vacuum of 10 millimeters. Drying time 60 minutes. No loss of weight after 45 minutes. Sample melted quickly and had dried appearance after six minutes.
8	75,862	Vacuum of 30 millimeters. Drying time 60 minutes.
Control	70,625	

The people at the Squibb Laboratories attributed the lower activity of sample 8 and the control to the fact that both specimens had been kept in solution in a frozen state for several days after samples 5, 6, and 7 were dried.

In any event, we felt that the test results showed that no harmful effects appeared when the dehydration took place with vacuums of the order of 10 millimeters. These initial tests have been repeated many times, always with the same result—no loss in potency.

In the above tests, it may appear that it is possible to freeze-dry with high vacuum in times varying from one

[2] Earl W. Flosdorf, Lewis W. Hull, and Stuart Mudd, "Drying by sublimation," *Jour. Immunology*, vol. 50, pp. 21–54; January, 1945.

to five hours. In our laboratory tests, the sample was in a thin-walled glass bottle which was connected to a manifold. Here the entire bottle was exposed to the warm air of the laboratory. In practice, where thousands of these bottles are placed in large vacuum tanks, no circulation of warm air takes place. The drying time by this method may take from eight to twenty hours.[3]

IV. A Radio-Frequency Bulk Reducer for Pencillin

As a result of these initial successes, much interest was exhibited by a number of pencillin producers. It seemed extremely desirable to review the work and consider how best to fit radio-frequency power into the picture.

After the penicillin mold is grown and the penicillin harvested, the material goes through a number of complex chemical processes from which it finally emerges as a weak water solution of a sodium or calcium salt of penicillin, with varying amounts of impurities. At the time that we were interested in considering the situation, it was the practice to freeze or shell this solution on the walls of a number of large glass bottles which were then attached to a manifold of a vacuum system. The vacuum was maintained at about 100 microns. The only heat supplied was by conduction through the walls of the bottles. After many hours, the material was considered to be dry and was then scraped from the bottles and pulverized. A measurement of potency, in Oxford units per milligram, was then made to determine the amount by weight that would be placed in the final ampoule or bottle. Since it was necessary to maintain a high degree of sterility, this operation was done in an air-conditioned box containing an analytical balance, a tray of penicillin powder, a rack of bottles, and the necessary loading tools. The operator manipulated the apparatus by inserting his arms into a pair of rubber gloves that were anchored to two openings in the box and by peeping through a small glass window in the wall of the box. This process was slow and expensive, as well as tedious and inaccurate.

We were told that most processors were considering a modification in which freeze-drying in the large bottles would be halted at a point where the activity of residue would be between 10,000 and 100,000 units per cubic centimeter. The material would then be allowed to melt and the liquid would be assayed for potency. Depending on the activity attained, between one and ten cubic centimeters of material could be accurately measured into each final container. Then a rack of final containers would be frozen and inserted in a large vacuum chamber and the pressure reduced to about 100 microns, for the final drying. Because of this change of procedure, it was decided that a radio-frequency bulk reducer was first in order of importance. The bulk reducer could then be used to remove sufficient water to concentrate to a potency of 100,000 units per cubic centimeter, after which one cubic centimeter of the material would be measured into each of the final containers and taken down to complete dryness by the freeze-drying high-vacuum chambers. The twofold advantage of the radio-frequency bulk reducer is that the expensive high-vacuum bulk reducer and refrigeration system is eliminated and the output of the final freeze-drying cabinets is increased because only one cubic centimeter of water is removed from each final container.

The first experiments in bulk reduction were conducted with a laboratory oscillator which could be changed readily to a number of frequencies. The frequencies investigated particularly corresponded to the frequencies of commercially available oscillators.

The experimental arrangement is shown in Fig. 1. The penicillin was contained in the large bottle shown at the

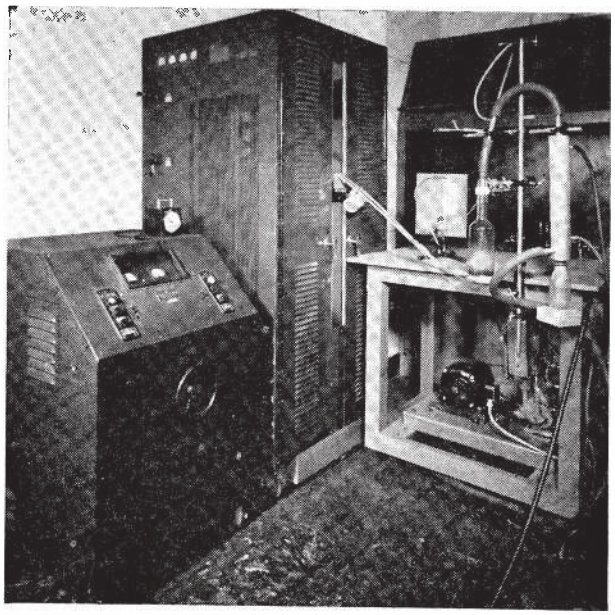

Fig. 1—First experimental bulk reducer.

table's edge. The tall chimney was necessary to prevent losses of material due to splashing. The electrodes were simply thin sheets of metal taped to the outside surface of the bottle. The bottom of the bottle was made concave so the load presented to the oscillator would remain fairly constant throughout the concentration cycle. This enabled us to use wider electrodes and still preserve this constancy of load. With a flat bottom, the liquid was sometimes concentrated below the level of the electrodes so that there was danger of ionization in the air space and sometimes arcing from the electrodes.

Attempts were made to operate at a frequency of 10 megacycles, but we were not able to overcome sparking at the electrodes. Further experiment showed that, at a frequency of 28 megacycles, there was little danger of electrode trouble, provided the concave bottom was used.

[3] See p. 38 of footnote reference 2.

A Beach-Russ vacuum pump, of the wet type, with a capacity of six cubic feet per minute, was used throughout the experiments with the bulk reducer and in the final model. The water vapor was passed into a water-cooled condenser so the pump was not forced to handle large quantities of vapor.

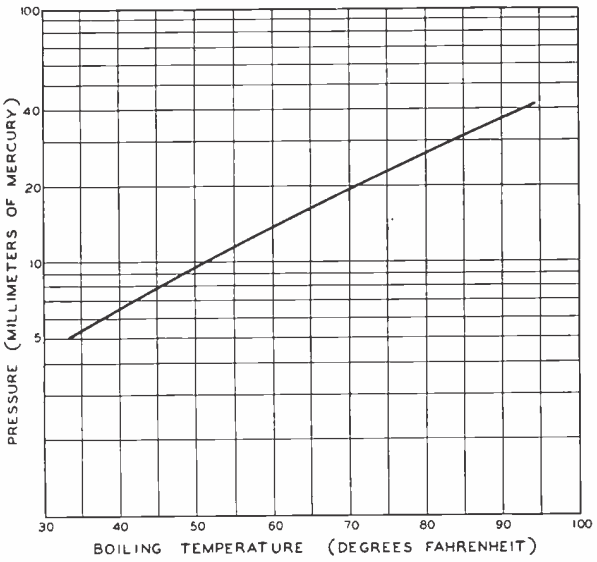

Fig. 2—Boiling temperature versus pressure.

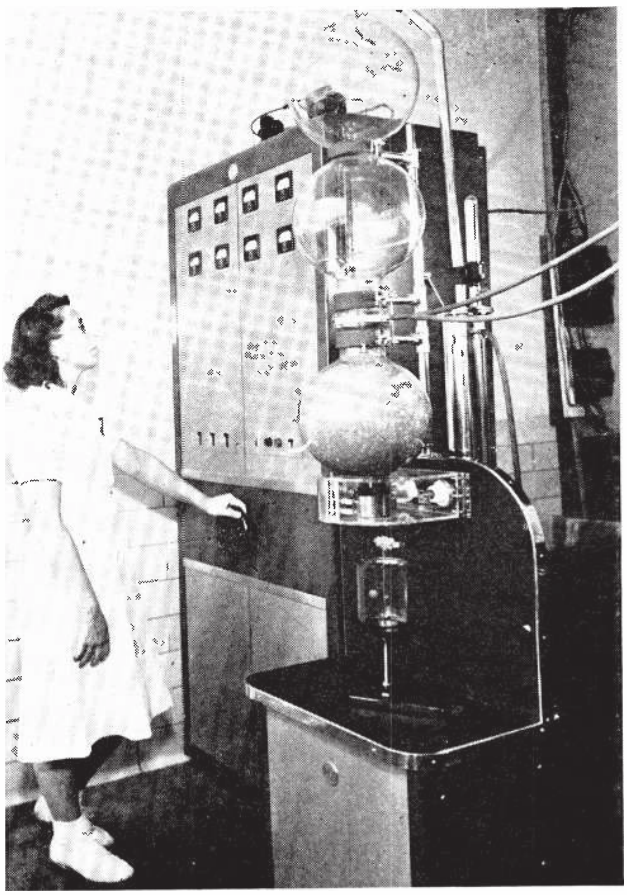

Fig. 3—Pilot bulk reducer in operation at Squibb Laboratory

A large number of experiments was carried out to learn the necessary technique for a practical system. Further tests were necessary to determine the safe range of temperatures and pressures which could be used without harming the penicillin. The temperature at which water boils as a function of pressure is shown in Fig. 2. While much of our operation took place at a pressure between 10 and 20 millimeters of mercury, we have run the equipment at pressures up to 40 millimeters without loss in potency of the penicillin.

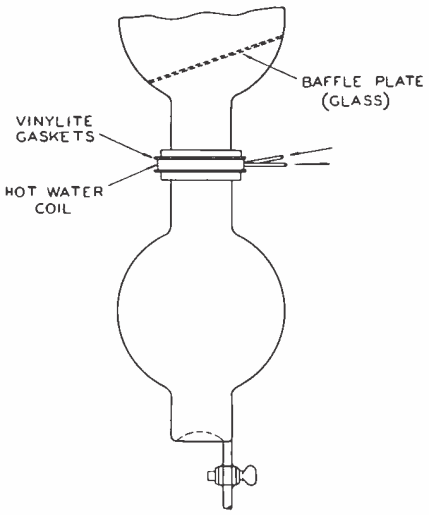

Fig. 4—Diagram of bottles with baffle plate and water coil in place.

A pilot unit was next constructed. The oscillator consisted of two RCA-833A vacuum tubes acting as a conventional oscillator at 28 megacycles, with a power output of two kilowatts. Fig. 3 shows the equipment in operation at Squibb's plant. The three large glass bottles provide room for foaming of the liquid when the vacuum is applied. Penicillin solution is extremely foamy so that our efforts in suppressing the foam were extensive. A baffle plate was inserted in the middle bottle. Also, a coil made of silver-plated copper tubing was inserted between the bottom and the middle bottles. The arrangement is shown in Fig. 4. Warm water (125 degrees Fahrenheit) was passed through this coil. When the foam and bubbles rise and contact the warm coil, the part of the bubble in contact with the coil evaporates and the bubbles collapse. This arrangement has been extremely successful in the operation at the Squibb laboratory.

In connection with the foaming problem, it might be mentioned that the excessive foaming difficulties were encountered at a time when most penicillin solution carried a large amount of impurities. Observations made recently show that the penicillin solution now being produced by most manufacturers has improved in characteristics to such an extent that neither the baffle plate

nor the hot-water coil need be used. Actually, the most violent foaming only fills the lower half of the bottom flask.

In using the bulk reducer, the sequence of operations is as follows: The hot-water supply for the bubble-breaking coil and the cold-water supply for the condenser are turned on and the vacuum pump started. When a liter of material is ready for treatment, a flask containing the solution is placed beneath the bottom bottle and the pet cock is opened. The penicillin solution is thus sucked up into the bottle. The pet cock is then closed and the oscillator turned on. With full power applied, 1000 cubic centimeters of liquid will be reduced to 100 cubic centimeters in eighteen minutes.

After turning off the oscillator, the vacuum pump is stopped and the relief valve is opened. Then the pet cock below the bottom bottle is opened and the penicillin solution drained from the bottle. After this operation, the pump is started and a new supply of penicillin is drawn into the bottle.

V. Drying in the Final Container

In Section III, the results of early experiments were reported. Here the drying was carried out in large test

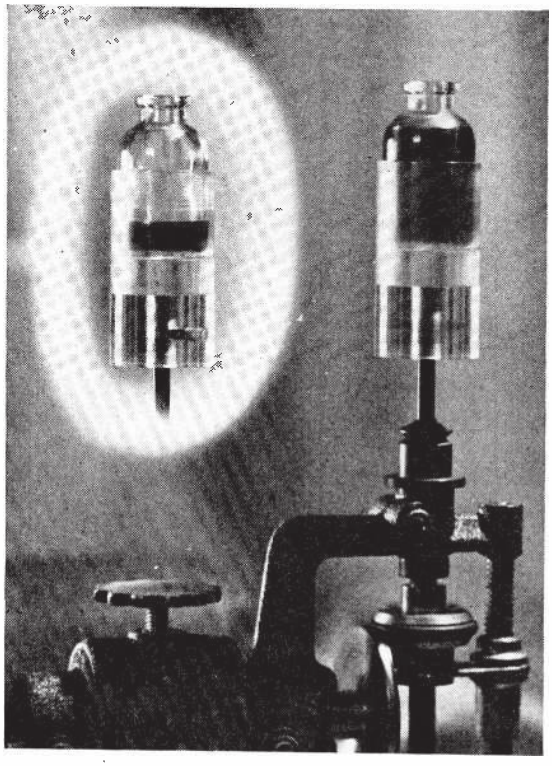

Fig. 5—The bottle is placed in a plastic cup. The bottle at the right is rotating at a speed of 3000 revolutions per minute. The liquid forms a thin film on the vall of the bottle.

tubes or ampoules. The material spattered up on the walls of the container when the vacuum was applied and spattered again when the radio-frequency power was turned on. This resulted in a messy appearance when finally dried. However, we were interested in the effect on the activity and for the moment were not concerned with appearance. When later attempts were made to

Fig. 6—Samples of penicillin dried by spinning in a radio-frequency field. Each bottle contains 100,000 units of penicillin, with varying amounts of impurities.

dry in the final bottle, it became apparent that it was almost impossible to keep all the material in the bottle. Initial application of the vacuum usually resulted in loss of a certain amount of solution due to spattering. After the application of power, severe bumping sometimes entirely emptied the bottle. Numerous expedients were resorted to in an attempt to solve this problem. Rotating the bottle at high speed during the evacuating and drying period revealed that this was a way to eliminate these difficulties. Fig. 5 illustrates this action. The bottle on the left contains about one cubic centimeter of penicillin solution. The same bottle is shown on the right, rotating at a rate of 3000 revolutions per minute. The liquid and solids in the liquid are then formed in a thin layer on the walls of the bottle. The force on the solids at this rotational speed is estimated to be at least one hundred times the force of gravity. When vacuum is applied, no material is lost. Then, as radio-frequency power is applied, the material dries in a thin film on the side of the bottle with a rather pleasing appearance. Dried samples may be seen in Fig. 6. A single-unit drier consisting of a plastic cup driven at a speed of 3000 revolutions per minute and a set of electrodes is shown in Fig. 7. This unit was found to be very useful in the laboratory, and several hundred samples of penicillin solution have been dried under various conditions with this equipment. With approximately 20 watts of power at 30 megacycles, it is possible to remove most of the moisture from one cubic centimeter of solution in three minutes. Typical data taken during a drying cycle is shown in Fig. 8. It may be seen that most of the water is removed in the first 60 seconds. The rate of drying

progressively decreases as time passes. Measurements of the Q factor of the circuit taken during the drying

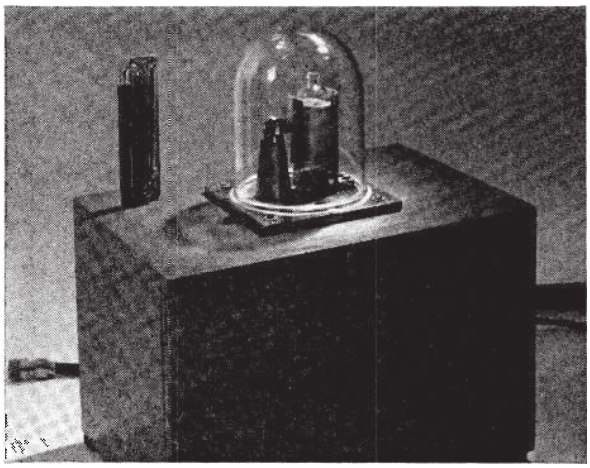

Fig. 7—A laboratory arrangement for drying one bottle at a time.

cycle are also shown in Fig. 8. As the material dries out, the Q becomes high so that there is quite a change in loading of the oscillator during the drying period. At the

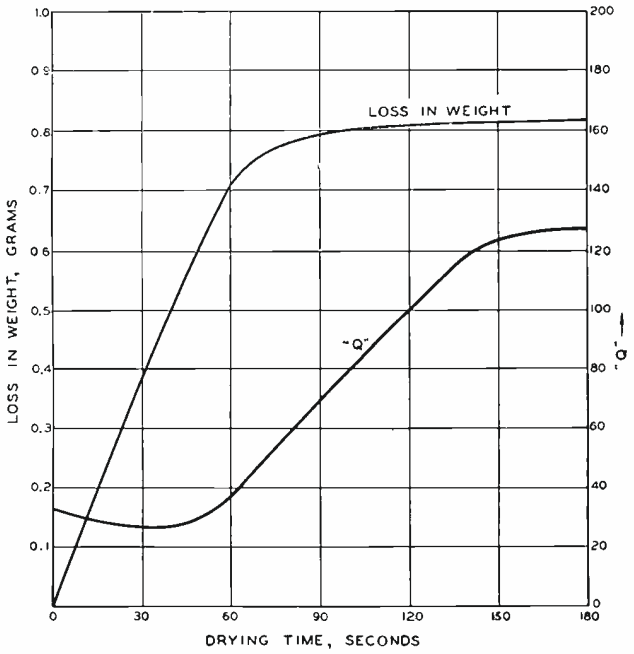

Fig. 8—Drying rate and Q of a single bottle as a function of time.

end of three minutes, the moisture content is reduced to about 4 per cent. Application of radio-frequency power for longer periods will reduce the moisture content still further. However, by the time the moisture content has been reduced to 4 per cent, the material is very stable and will stand much higher temperatures than it does when in the liquid condition. This allows us to introduce another step which is important in the construction of final equipment, since it permits the use of a minimum number of rotating cups. The bottles are transferred to metal plates which are heated by ordinary electric heaters. A bell jar is then placed over the heater plate and the system evacuated. Since the ma-

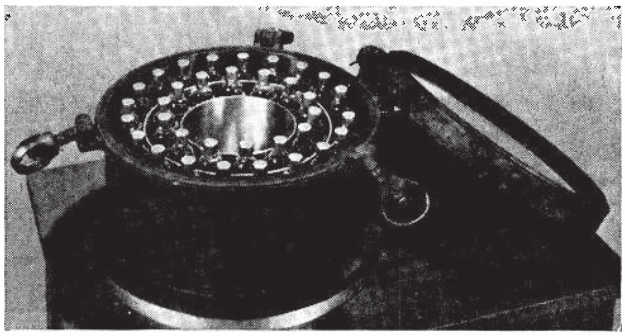

Fig. 9—An experimental drying chamber which holds thirty-four bottles.

terial is dried on the sides of the bottle in a thin film, heat conduction through the glass bottle to remove the last traces of moisture is efficient.

Early in the investigation, several samples of penicillin solution were dried and tested for activity and moisture content. In each case the bottle was rotated for three minutes in a radio-frequency field, with a vacuum of 50 millimeters of mercury. Then the bottles were removed from the radio-frequency field and placed in a metal box which in turn was placed in a bell jar, with a vacuum of 8 millimeters of mercury. An electric heater, thermostatically controlled, heated the metal plate which supported the bell jar to a temperature of 65 degrees centigrade. At the end of the run, the bottles reached a temperature of 50 to 55 degrees centigrade. The conditions of test as well as activity measurements are show in Table V.

TABLE V

Sample	Time in Bell Jar	Activity Oxford Units	Number of Activity Tests
Control	—	95,954	8
Control	—	103,441	6
204	2 hours	115,233	4
205	2 hours	101,853	4
206	2 hours	101,561	4
212	1 hour	108,265	4
214	1 hour	110,349	4

The moisture determinations were as shown in Table VI.

TABLE VI

Time in Bell Jar	Per Cent Moisture (Average of Three Samples)
2 hours	0.43
1 hour	0.60
Zero	4.13

With these and similar data at hand, the construction of a system which would handle large numbers of bottles was started. A unit of the system is shown in Fig. 9. A port-hole frame is used as a vacuum chamber. Thirty-four plastic cups are mounted on the peripheries of two

circles. An electrode, insulated from ground may be seen between the two rings of bottles. An inner metal ring and the wall of the port form the two ground electrodes. Radio-frequency power is fed in through a vacuum-tight insulating bushing. Each of the plastic cups is individually gear driven at a speed of 3000 revolutions per minute.

Fig. 10 shows a circular table which supports six of these chambers. Each chamber is subjected to radio-

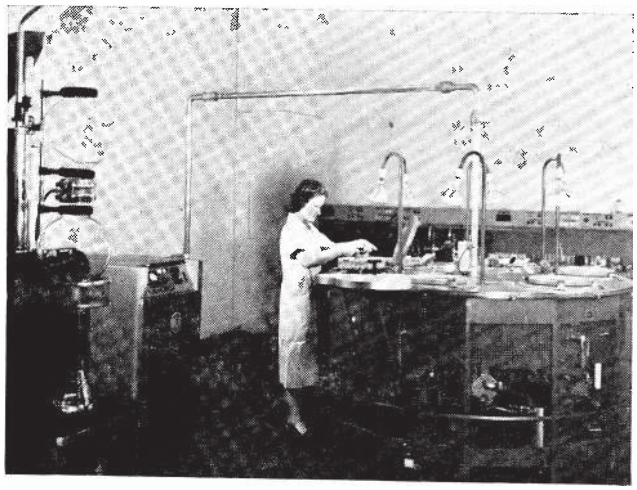

Fig. 10—A circular table with six drying chambers. This equipment dries 2000 bottles per hour. The infrared lamps prevent condensation on the cold lids of the vacuum chambers.

frequency power for three minutes. A rotary switch is used so that three chambers are connected to the oscillator at one time. One chamber is in the wet stage; that is, it is in the first third of its drying cycle. Another chamber is in the second third of its drying cycle, while a third chamber is in the last stage of the drying cycle. At the end of one minute, the chamber containing dry bottles is switched from the oscillator and a fresh chamber is connected in the group. Thus the oscillator remains essentially fully loaded at all times. An examination of Fig. 8 reveals the reasoning behind this procedure. In addition, the automatic load-tuning circuit incorporated in the RCA-2B oscillator insures complete stability with respect to power output. While three chambers are being dried, the fourth is in the process of unloading, the fifth is being loaded, and the sixth is in the initial stages of evacuation. Since one chamber of thirty-four bottles is unloaded every minute, over two thousand bottles are processed each hour.

The bottles are next loaded into aluminum trays and the trays are placed on the electrically heated bases shown in Fig. 11. The metal domes are then closed and evacuated to about 5 millimeters of mercury. After one-half hour in these auxiliary domes, the bottles are removed for capping.

The equipment shown in Fig. 10 is largely automatic. The operator's duties consist of operating the vacuum applicator valves and vacuum release valves on the side of the table, as well as opening the lids of the chambers, removing the processed bottles, and inserting new bottles to be dried. When the operator closes the lid to a chamber, a microswitch is actuated and the bottles begin rotating. A green pilot light at each chamber indicates that the chamber may be opened. A red pilot light shows that radio-frequency power is being applied to the chamber. At the end of each minute, a timer turns off the oscillator, operates the rotary switch so that one

Fig. 11—The auxiliary drying chambers.

chamber is dropped out and a fresh chamber connected, and then turns on the oscillator. If the operator has not yet processed this fresh chamber and thrown the vacuum-applicator valve to the final position, the oscillator will not turn on, and an amber pilot light will indicate the chamber that is delaying the proceedings. When the vacuum-applicator valve is finally thrown, the one-minute cycles will then be resumed.

VI. Electrical Conductivity of Penicillin

It has been suggested many times that we reconsider the situation and attempt to dry in the frozen state. Since we have shown that our method of drying produces a dry product with no loss in activity, there seems to be no point to the introduction of greater complications of higher vacuums and colder condensers. In addition, the high voltage required in the presence of the more perfect vacuum seems to be an obstacle which will not be solved easily. Early in this paper, it was stated that the voltages necessary to develop power in the frozen material were markedly higher than for the liquid solution. This point may be illustrated by a specific example.

The power generated in a one-centimeter cube of material is

$$P(\text{watts}) = E^2\sigma$$

where σ = conductivity of the material in mhos for a centimeter cube

E = electric intensity in the cube in volts per centimeter.

Then for one watt generated in the cube, the electric intensity is

$$E = \frac{1}{\sqrt{\sigma}}.$$

This electric intensity may be regarded as the voltage required between opposing faces of the cube.

Murphy and Morgan[4] show that the conductivity of ice increases as a function of frequency but flattens off completely when the frequency is greater than 10,000 cycles. For ice at -0.8 degrees centigrade, they show a conductivity of 4.15×10^{-7} mhos for a centimeter cube. When substituted into the above equation, it is seen that the voltage across the one-centimeter cube for one watt is 1550 volts. However, this temperature is very close to the melting point of ice at atmospheric pressure. A few degrees drop in temperature reduces the conductivity appreciably. At -45.8 degrees centigrade, a temperature where freeze-drying is usually carried out, the conductivity has dropped to 10^{-8} mhos for a centimeter cube, with a resultant field intensity of 10,000 volts per centimeter.

Measurements on typical penicillin solution in the liquid state (20 degrees centigrade) show that the conductivity may be expressed as

$$\sigma = 10^{-6}A$$

where A is the activity measured in Oxford units per cubic centimeter. Thus when the activity is 100,000 units per cubic centimeter, the conductivity is 0.1 mhos for a centimeter cube, and the field intensity necessary to generate one watt in a centimeter cube reaches the remarkably low value of 3.16 volts per centimeter.

In addition to these quantitative relations, the difficulties of coupling radio-frequency energy to ice may be realized by means of a simple experiment. A set of electrodes which will hold a penicillin bottle is mounted on the capacitor terminals of a conventional Q meter. Then if a bottle containing several cubic centimeters of frozen penicillin solution and an empty bottle are successively plugged into the electrodes, it is impossible to detect a difference in the reading of the Q meter.

[4] E. J. Murphy and S. O. Morgan, "The dielectric properties of insulating materials," *Bell Sys. Tech. Jour.*, vol. 18, p. 512; July, 1939.

VII. Conclusion

Experiments leading to the development of a successful method of dehydrating penicillin solution by means of radio-frequency heat have been presented. The process has been divided into three parts: (1) bulk reducing of the solution to achieve an activity of 100,000 units per cubic centimeter; (2) drying one cubic centimeter of the concentrate in the final bottles until the moisture content is reduced to four per cent; and (3) completing the drying in auxiliary chambers. The equipment described is capable of producing 2000 dry bottles each hour, using inexpensive vacuum pumps and simple condensers. The whole system operates with a minimum of maintenance.

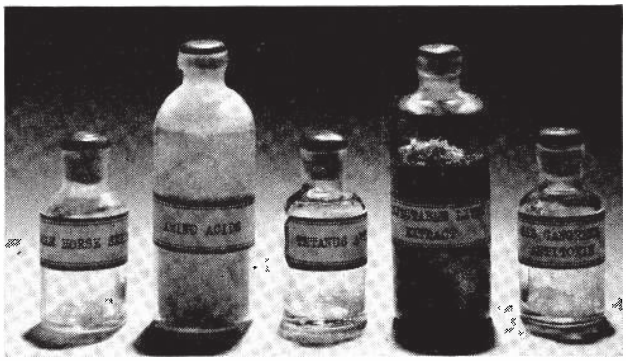

Fig. 12—Representative pharmaceuticals dried by the radio-frequency method. From left to right: whole horse serum, amino acids, tetanus antitoxin, injectable liver extract, gas gangrene antitoxin.

When the bottles are removed from the auxiliary heaters, they are closed with rubber stoppers, and aluminum caps are pressed on to hold the stoppers in place. The bottles may then be stored for long periods of time until needed. At that time, sterile water is injected through the rubber stopper with a hypodermic syringe, the penicillin readily dissolves in the water, and the solution is withdrawn into the syringe.

Because the techniques described in this paper are so different from conventional methods of drying of pharmaceuticals and biologicals, it is difficult to predict what will happen to the many products which might be dried by these methods. Until a broad experience has been built up, it is necessary to submit each product to experiment. The authors have dried a limited number of products with results which show great promise. Representative samples are shown in Fig. 12.

A Vacuum-Contained Push-Pull Triode Transmitter*

HAROLD A. ZAHL†, ASSOCIATE, I.R.E., JOHN E. GORHAM†, ASSOCIATE, I.R.E., AND GLENN F. ROUSE†

Summary—**A 600-megacycle transmitter is described which varies from the usual triode design in that the resonating grid and plate circuits are contained in vacuum and form an integral part of the grid and plate structures. The design described, while applicable for continuous-wave operation, covers particularly United States Army-type tube VT-158 constructed only for pulse operation. Peak powers of 200 to 300 kilowatts can be obtained under proper conditions of operation.**

I. Introduction

A FEW YEARS ago Major-General Roger B. Colton, then Director of the Signal Corps Laboratories, Fort Monmouth, N. J., noticed how much difficulty was being experienced with radio-frequency sparking and loading of more or less conventional ultra-high-frequency high-power, triode oscillator circuits. He suggested that most of the troubles would be eliminated if the oscillators were constructed with the circuits contained in a vacuum. This paper will describe a transmitter which was subsequently built so as to incorporate most of the radio-frequency circuits inside the vacuum envelope.

II. Design Description

The illustration represents a tube constructed by the authors which can be made to oscillate in a narrow frequency band between 200 and 700 megacycles. Although satisfactory continuous-wave oscillators of this type have been built, the main application has been in the field of high-power pulse oscillators capable of furnishing about two- or three-hundred kilowatts of radio-frequency power.

Fig. 1 shows a general view of one model of this type of tube. The two vertical, parallel rods at the top of the tube form a balanced-line output circuit which is coupled directly to the plate circuit. The parallel transmission line serves in a rough way as a matching circuit to connect the tube to a 50-ohm concentric line, such as is often used to transmit power in this frequency band.

The uppermost loop, or plate loop, is connected directly to the anodes in such a way as simultaneously to reduce the problem of connecting the oscillating circuit to the plates, and by virtue of the flat surface of the loop, increase the effective radiating surface and power dissipation of the plates. The plate loop, made up of two U sections, serves to maintain the symmetry of the circuit, and of course each of the two U sections, in effect, resonates with half of the interelement capacitances. Thus for a given half-loop length and set of interelement capacitances, the tube may be made to oscillate at a higher frequency than if only one half loop was used.

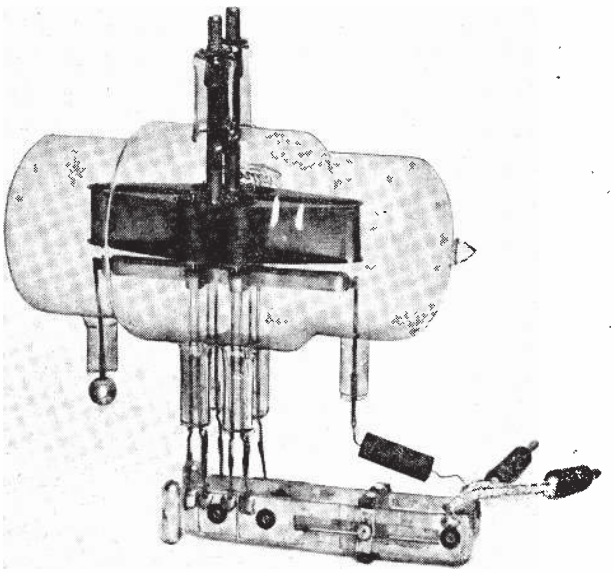

Fig. 1—Front view of transmitting tube.

It has been found advantageous to make both the upper and lower loops of tantalum, since this metal is relatively easy to work and is well known as a good getter. Production models of this general design depend entirely on the tantalum for getter action.

A word should be said about the two anodes in parallel, which in turn operate in push pull with two more anodes in parallel. Several successful continuous-wave oscillators were built with single anodes on each side, but when the tube was pulsed to obtain peak powers several thousand times larger than the average power, it was found that the main limitation in tube output was determined by the amount of available peak emission. The parallel-anode type of construction thus doubled the available peak emission for a given type of element configuration.

The lower loop is the grid loop. Its primary purpose is to obtain grid driving power from the plate circuit. It has been found that relatively little of the power dissipated in the grid cages is conducted along the grid

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† Signal Corps Engineering Laboratories, Bradley Beach, N. J.

wires to the external loop, and therefore it can have less radiating surface than the plate loop. In normal operation, the anodes are run at a red heat, and the filaments are run at a somewhat higher temperature than is usually used. This results in having the grid cages located between two very hot elements, and they are therefore very sensitive to grid contamination and subsequent blocking during oscillation. Under such conditions when plain tantalum wire is used in the cages, the tube becomes sufficiently contaminated to be inoperative in about 24 hours. This difficulty has been overcome completely by the use of Eimac "X" grid cages,[1] and without exception the end of tube life is determined by loss of emission, as it should be, after many hundreds of hours.

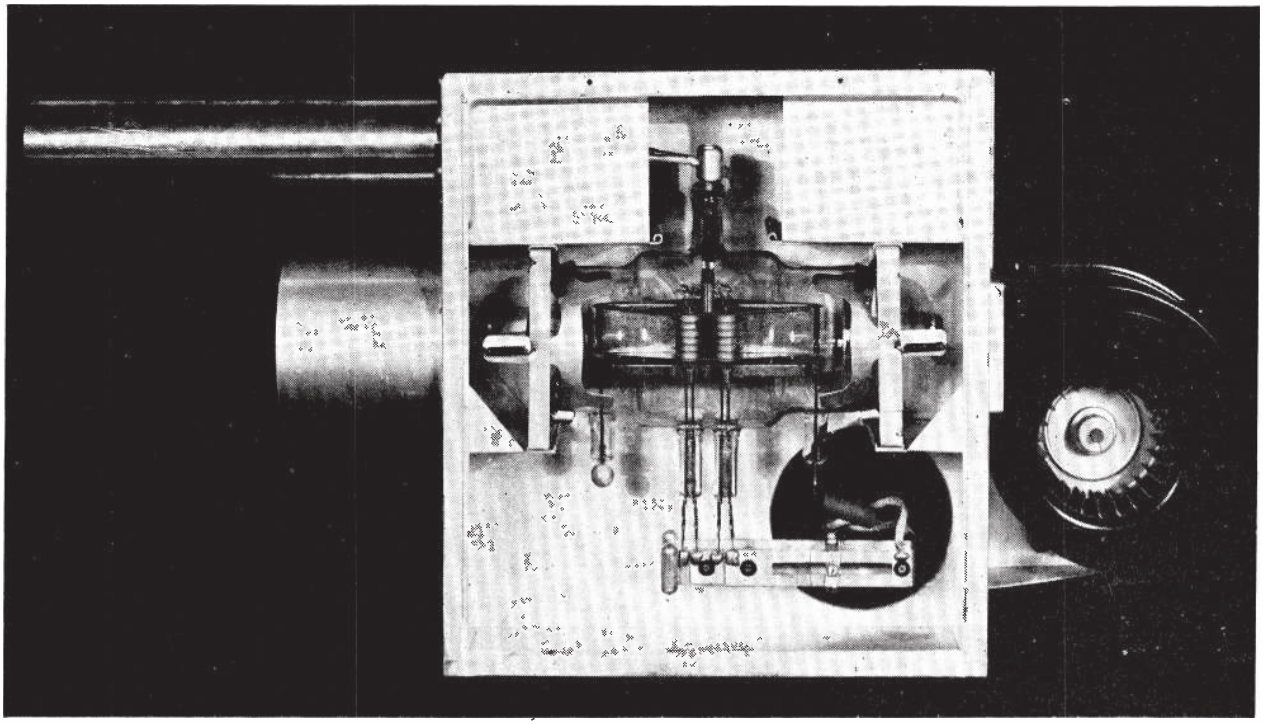

Fig. 2—Front view of transmitting tube and shield.

The filaments are made of carbonized, thoriated tungsten wire and run at a temperature which gives an emission of about 200 milliamperes per watt. In order to obtain satisfactory operation, an external, parallel transmission line is attached so that the two filaments on the same side of the tube are tied together for radio-frequency considerations. Several such transmission lines have been designed with which it is possible to run all four filaments in series if a higher voltage, lower current source is to be used. Since it is most convenient to connect the plate output directly to the output transmission line, the tube is usually run with the plate circuit at direct-current ground potential, and a negative high voltage applied to the filaments. The filament line is tuned so that the filaments are effectively points of zero radio-frequency voltage. It has been found that this external line may be either parallel or at right angles to the axis of the tube. While it is usually preferable to have the filament line at right angles, since radio-frequency corona is less troublesome, where space is important it is mounted parallel with the axis of the tube.

Four filaments, instead of two larger ones, were used since several advantages were thus obtained. The filament spirals could be made more compactly and therefore less susceptible to sagging, and the filament power could be dissipated in two anodes instead of one, with attendent lower element temperatures. This construction also allows closer spacing of the elements, an important advantage at these frequencies where transit time must be considered. The obvious disadvantage of this multiple-filament design is its complexity, and it must be said that the highest tribute is due the several tube manufacturers for their ingenuity in overcoming the production difficulties by the development of very clever techniques, tools and jigs, and particularly to Mr. W. Eitel and Mr. J. A. McCullough of Eitel McCullough, Inc., for early assistance in establishing the mechanical design of the production-type tube.

III. Shielding

If the oscillator is used without a shield, about 80 per cent of the power output obtainable with a shield is

[1] H. E. Sorg and G. A. Becker, "Grid emission in vacuum tubes," *Electronics*, vol. 7, pp. 104–109; July, 1945.

realized. In general, the shielding found most successful is shown in Fig. 2 and consists of a rectangular metal box with two central transverse shelves which serve to hold the tube, and to separate the cavity containing the tube from the cavities containing the output and filament circuits. The output cavity has been designed to act as a "bazooka" or radio-frequency choke at the end of the concentric line, and thus accomplish the transition from the balanced output of the tube to the unbalanced, concentric transmission line. The filament-line cavity serves primarily to contain the radiation, but its shape also determines the magnitude of standing waves at the point where the filament pins are sealed through the glass envelope.

In contrast with the situation at the plate output seals, the filament leads inside the envelope act as a rough transformer to produce a high radio-frequency voltage at the filament seals. At extremely high voltages and powers, this causes corona and subsequent detuning of the oscillator in an erratic manner. This can be avoided for peak powers greater than 300 kilowatts by use of a vertical, external filament line and proper design of the cavity. The frequency of the oscillator does not seem to be especially sensitive to the type of shield used.

IV. Operating Characteristics

A typical set of characteristics is shown in Table I. (Joint Army-Navy terminology is used.)

TABLE I
DESCRIPTION: ULTRA-HIGH-FREQUENCY PULSED OSCILLATOR VT-158.

Ratings:	E_f	I_f	E_b	E_c	I_b	I_c	P_p	p_i	Modulation
Absolute:	volts	amperes	kilovolts direct current		amperes	—	watts	kilowatts	
Maximum:	10.5	10.5 (Note 1)	30 (Note 2)		70	—	400 (Note 3)	1500	Plate
Test conditions:		10.2	—	—	—	—	—	—	

Reference	*Test: Test Conditions*		*Acceptance Limits* Minimum	*Acceptance Limits* Maximum	
F-6b(3)	*Bump: Angle = 10 degrees (Note 4)				
F-6b(4)	*Bump: Angle = 3½ degrees (Note 4)				
—	Filament voltage (Note 1)	E_f:	9.8	10.2	volts
—	†Emission: $e_b = e_c = 3000$ volts	i_s:	70	—	amperes
—	†Pulse operation $E_b = 20$ kilovolts direct; current pulse repetition rate = 240 pulses per second $F = 595$ to 600 megacycles, pulse width = 1 microsecond	P_o:	150	—	kilowatts
F-6p	*Capacitance:	C_{gp}:	11.8	16.0	micromicrofarads
		C_{gf}:	11.9	16.1	micromicrofarads
		C_{pf}:	1.25	1.69	micromicrofarads
—	*Gas Test: pulse operation: (Note 5)				
F-4	Life Test: pulse operation:		500	—	hours
F-4B	Life-Test end point:	P_o:	135	—	kilowatts

Note 1: Measured for each filament separately.
Note 2: The tube is self-biased (80 ohms 5W, grid resistor).
Note 3: A minimum of 60 cubic feet of free air per minute is required across the tube for a plate dissipation of 400 watts.
Note 4: The hammer arm shall be allowed to strike the glass envelope at an angle of 90 degrees to the plane of grid leads.
Note 5: The tube shall be subjected to the pulse-operation test three times for two minutes at two-minute intervals applying all voltages including filament voltage and cooling devices, simultaneously. The temperature of the bulb of the tube shall not exceed 50 degrees centigrade at start of this test. There shall be no indications of gas or seal failure during or at the conclusion of this test.

Although the optimum output is obtained at a definite frequency, determined by the geometry of the elements inside the envelope, it has been observed that the external filament line may be used to shift the operating frequency over a bandwidth of 30 megacycles between half-power points. This feature is of considerable importance in allowing some tolerance in manufacturing, and in adapting the tube to several different types of radio-frequency circuits. It may be said that ordinary vacuum-tube production tolerances may be used to obtain tubes (from several different manufacturers) which all peak within a few megacycles of the same frequency.

The tube may be pulsed by biasing the grid beyond cutoff and applying suitable pulses to drive the grid positive several hundred volts for the required pulse interval. In another method of pulsing, the grid may be connected to the common radio-frequency point of the filament circuit through an appropriate resistor, and the filaments pulsed negatively with respect to the plate by as much as 30 kilovolts. Although efficiencies as high as 40 per cent have been observed for experimental tubes, the oscillator efficiency for production tubes is about 25 per cent under optimum conditions, and is constant for applied voltages greater than several kilovolts. This is interpreted as meaning that transit-time effects are negligible above this voltage, and rough calculations show that this should be the case. Frequency stability has been checked only during pulse operation, and within the uncertainty due to the Fourier components of the pulse, no instability could be found, nor could any frequency modulation be detected. An interesting feature of the tube characteristics is that the anode high-voltage filament power and blower can all be simultaneously turned on and off without any previous warm-up. No bad effects due to this practice have been observed.

V. Theory

Theoretical investigation of the properties of this type of design has proved to be difficult, primarily because of uncertainty about the current distribution in the closely spaced plate and grid loops at the frequencies mentioned. The general type of circuit is not new; similar circuits having been treated in papers by Holburn,[2] Mesny,[3] Gutton and Pierret,[4] and Denhardt,[5] and summarized in a paper by Wenstrom.[6] All of these treatments are concerned essentially with an experimental determination of the circuit characteristics.

Since in pulse operation the electron transit time is not appreciable, the tube probably should be capable of running with an efficiency of at least 50 per cent. Accordingly, the conventional-oscillator-design principles advanced by Prince about 1923 were applied to this tube by Lewis Greenwald, of this laboratory.

[2] F. Holborn, *Zeit. für Phys.*, vol. 6, pp. 328, 1921.
[3] Mesny, *L'Onde Electrique*, vol. 3, pp. 25–37; January, 1924.
[4] C. Gutton and E. Pierret, *L'Onde Electrique*, vol. 4, p. 387; 1925.
[5] A. Denhardt, *Zeits. für Hochfrequenz.*, vol. 35, pp. 212–223; June, 1930.
[6] W. H. Wenstrom, "An experimental study of regenerative ultra-short-wave oscillators," PROC. I.R.E., vol. 20, pp. 113–131; January, 1932.

These principles have been found to be quite adequate for ultra-high-frequency tubes so long as the transit time is small. The interloop coupling problem was avoided by considering the two loops and external load as a four-terminal network connected to the grids and plates, as shown in Fig. 3. It was assumed that this network maintained approximately 180 degrees phase difference between grid and plate and insured push-pull operation. On this basis, approximate explanations of many observed phenomena were made possible, and some improvement in efficiency was effected by increasing the plate-filament capacitance. However, the efficiency was not made to approach the value of 50 per cent. This may be due to use of incorrect effective values of interelement capacitances or to lack of sufficient information about the operation of the loops.

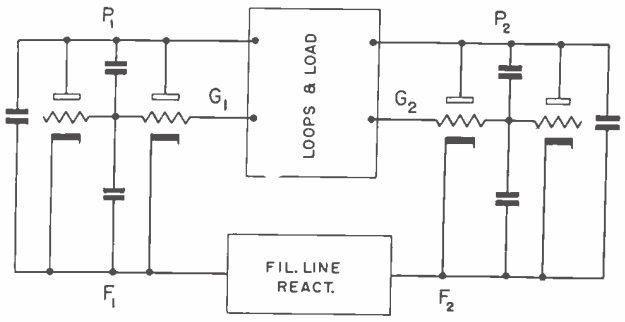

Fig. 3—Equivalent circuit of transmitting tube.

VI. Grounded-Plate, -Grid, and -Cathode Designs

It occurred to the authors, and to McCullough and Eitel in an unpublished communication, that the design herein described might be simplified by altering the internal construction so that the two anodes were tied together to have zero radio-frequency voltage difference (grounded plate). This would eliminate one internal tuned circuit, and would necessitate taking the power out at the filament line. Such a tube was built and it was found that almost exactly half the normal radio-frequency power could be obtained in this way. Subsequent tests on tuned-plate, tuned-grid tubes also showed that only half the power could be obtained from the filament lines, and work on grounded-plate tubes was then dropped without further investigation.

The authors attempted further designs involving grounded-grid and grounded-cathode construction, and the results were uniformly most unsuccessful, in that these types of tubes were never observed to oscillate. The grounded-grid construction was carried so far as to involve slits in the anodes to allow direct connection of the four grid cages by the shortest possible leads. The grounded-cathode tube was built around a rectangular box-type oxide cathode mounted between the two sides of the plate loop. In all cases, the element geometry was such as to have about the same amplification factor and transit time as for the tuned-plate, tuned-grid type of tube.

VII. Conclusion

This tuned-plate tuned-grid type of vacuum tube and circuit was developed a few years ago when low radio-frequency-impedance glass-metal seals had not been widely applied to tubes of this power and frequency. The subsequent development of such seals and corresponding tube improvement, especially in development of tubes which could be connected intimately with many different types of radio-frequency circuits which jointly covered a much wider band of frequencies, has been of great practical importance both in the war effort and in postwar applications. However, it is desired to point out one advantage of the tube of special importance for military use. Those who have seen extremely high-power pulse-transmitter circuits using the new low-impedance glass-metal-seal tubes are invariably impressed with the large size, weight, and complexity of concentric-line plumbing, a most descriptive term. Also, high-power pulse magnetrons for these frequencies are extremely large and heavy. Compared with these, the present tube is shipped from the tube manufacturer as a complete transmitter. The combined tube and shield weigh only about two pounds, occupy a much smaller volume, and are much simpler to make and assemble than are the newer type tubes and external oscillating circuits.

Tube type VT-158 was used principally in the light weight, early warning radar set AN/TPS-3, in both the European and Pacific theaters of operation.[7]

[7] H. A. Zahl and J. W. Marchetti, "Radar on 50 centimeters," *Electronics*, vol. 19, pp. 98–104; January, 1946.

Three New Antenna Types and Their Applications*

ARMIG G. KANDOIAN†, SENIOR MEMBER, I.R.E.

Summary—Three newly developed types of antennas are described. The radiation pattern of each is substantially omnidirectional in the horizontal plane. The first has vertical polarization, the second has horizontal polarization, and the third is elliptically or circularly polarized.

Variations of the above types, bandwidth considerations, tuning range, advantages, and limitations of each type are discussed, as well as the use of these antennas singly or in directive arrays for high power gain. Application to very-high-frequency and ultra-high-frequency broadcast, television, and link communication is briefly considered.

Photographs of experimental models giving construction details are shown, as well as measured characteristics of the type of antennas under consideration. Installation schematic of a typical array for frequency-modulation broadcasting is also shown.

Introduction

THREE new types of antennas have been developed for use primarily in the very-high-frequency and ultra-high-frequency spectrums. The radiation pattern of each antenna is essentially equivalent to that of a dipole; that is, it may be represented by a solid of revolution determined by a rotating figure of eight.

Type I, the Discone antenna, is intended primarily for vertical polarization, and, like a vertical dipole, gives an omnidirectional pattern in the horizontal plane. A distinctive feature of this antenna is its simplicity of construction and feeding. Its most important characteristic is satisfactory operation over a very wide band of frequencies (several octaves) without a substantial change of either input impedance or radiation pattern.

This type of antenna has wide applications wherever extremely wide frequency ranges are encountered and simplicity of mechanical design and installation are required.

Type II, a coaxially fed loop antenna, is intended primarily for horizontal polarization. The radiation pattern is omnidirectional in the plane of the loop. The radiators forming the loop are metallically supported from the mast or other supporting structure. Further, both supports and radiators form part of the coaxial feeding circuit. No balanced lines are used anywhere in the circuit. The bandwidth is controllable, though in general much narrower than with the type I antenna. No stubs are necessary to obtain a match to any common type of coaxial feeder of 50, 70, or 100 ohms.

The most important feature of this antenna is its simplicity of mechanical design and construction, and the ease with which a larger number of antennas may be "stacked" for high-degree directivity in the vertical plane while retaining omnidirectional radiation in the horizontal plane.

Typical applications of this type of antenna are frequency-modulation broadcasting, television, and general communication.

Type III antenna is similar to type II, except that at the center of the loop and perpendicular to it a vertical radiator has been added. The radiation pattern of type III is essentially the same as that of types I or II; the free-space field intensity at all points has both horizontal and vertical components in equal amounts. The type III, being a combination of an "electric" dipole (vertical radiator) and a "magnetic" dipole (horizontal loop), might, therefore, be called an "electric-magnetic" dipole.

Equality of amplitude of the two polarization components is not necessary as any desired ratio of amplitude as well as phase relationship between the horizontally and vertically polarized fields may be obtained.

The most interesting application of this type of radiator is in high-directivity arrays or in illuminating a highly directive parabolic reflector or horn for general communication application. The presence of both vertical and horizontal components, it is felt, will be helpful in reducing fading. There is also a possible application of this type of antenna to very-high-frequency and ultra-high-frequency broadcasting, where the receiving dipole could then be oriented for optimum signal-to-noise ratio.

Type I—The Discone Antenna

The Discone antenna, as the name suggests, consists of a disk and a cone whose apex approaches and becomes common with the outer conductor of the coaxial feeder at its extremity. The center conductor terminates at the center of the disk which is perpendicular to the axis of the cone and the feeding transmission line. Fig. 1 is a schematic of the Discone antenna with a tabulation of typical dimensions. Fig. 2 shows a Discone antenna.

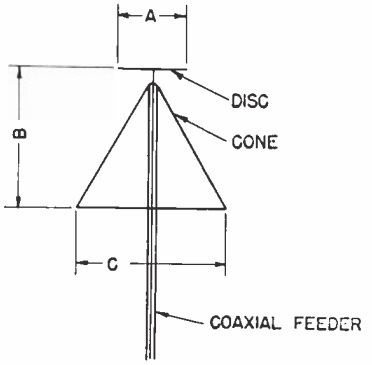

Fig. 1—Schematic diagram of the Discone antenna.

Cutoff Frequency	A	B	C
90 megacycles	18 inches	24 inches	20 inches
200 megacycles	9 inches	12½ inches	14 inches

The Discone antenna in its radiation behaves essentially as a vertical dipole. However, its change of impedance versus frequency is very much less than any

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† Federal Telephone and Radio Laboratories, New York, N. Y.

ordinary dipole of fixed length. The same is true of its radiation pattern.

From the circuit standpoint the Discone antenna is essentially a high-pass filter. It has an effective cutoff

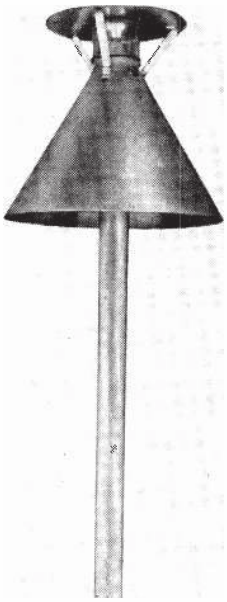

Fig. 2—Discone antenna for cutoff frequency of 200 megacycles.

frequency below which it becomes very inefficient, causing severe standing waves on the feeding coaxial line. Above the cutoff frequency, however, little mismatch exists and the radiation pattern remains substantially the same over a wide range of frequencies. The slant height of the cone is approximately equal to a quarter wavelength at the cutoff frequency.

Fig. 3 illustrates a typical mismatch versus frequency of a Discone antenna measured on a 50-ohm coaxial feeder.

Fig. 4 shows a typical measured radiation pattern of a Discone antenna, cut off at approximately 200 megacycles, measured every 50 megacycles up to 650. It is evident that, from cutoff (200 megacycles) all the way up to 650 megacycles, no drastic change in the radiation pattern has taken place. At the high-frequency end, however, the pattern does begin to turn upward. Investigation is now in progress to determine its characteristics at much higher frequencies.

The radiation patterns shown in Fig. 4 are measured patterns of the Discone antenna proper. As in most antennas with vertically polarized radiation, the supporting structure, in the present case the coaxial feeder, participates somewhat in the over-all radiation. This is due to currents induced in the supporting structure by the antenna. The amplitude of the induced currents in the present case is of the order of 5 per cent of the main antenna current and, hence, cause "scalloping" of the radiation pattern of approximately ± 5 per cent. For applications where it is required, a suppressing means, such as, for example, radial rods clamped on the supporting structure below the open end of the cone, may be used to prevent coupling between the antenna and the supporting structure.

An interesting application of the Discone antenna occurs when the cone of the antenna serves as the complete housing for the transmitting or receiving equipment.

A variation of the Discone antenna which has some useful applications is where the lower end of the cone is "grounded"; that is, made common with a large conducting surface.

Fig. 5 shows another experimental Discone antenna with a cutoff frequency of approximately 90 megacycles. Its performance is in general quite analogous to the small unit just described.

The Discone antenna may be visualized as a radiator intermediate between a conventional dipole and an electromagnetic horn. At the low end of its operating band, it behaves very much as a dipole; at much higher frequencies, it becomes essentially a horn radiator.

For information on antennas related to but not entirely equivalent to the Discone, the reader is referred to several investigators.[1–3]

Type II—Coaxially Fed Loop

Type II antenna is a loop radiator. This type is sometimes referred to as a "magnetic" dipole. An experimental model of the present type for approximately 550 megacycles is shown in Fig. 6.

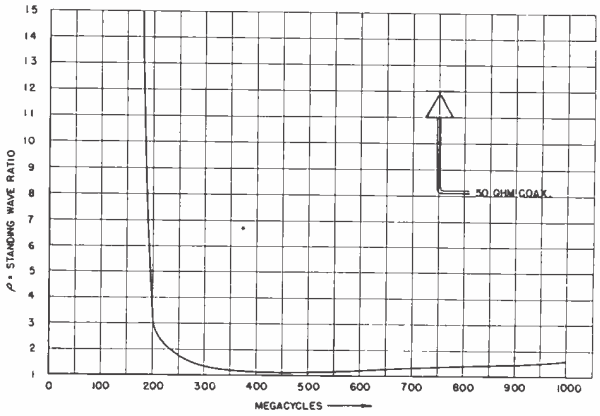

Fig. 3—Mismatch versus frequency of Discone antenna for a cutoff of 200 megacycles.

Loop antennas for very-high-frequency and ultra-high-frequency application have been described by several investigators.[4–7] While the present type of loop has the same radiation characteristic as an equivalent-size loop antenna previously described, its mechanical and electrical design is considerably different and offers some advantages and new possibilities in the application of the loop antennas.

[1] S. A. Schelkunoff, "Electromagnetic Waves," D. Van Nostrand Company, New York, N. Y., 1943, pp. 441–459.

[2] G. C. Southworth, United States Patent Nos. 2,231,602 and 2,369,808.

[3] W. L. Barrow, L. J. Chu, and J. J. Jansen, "Biconical electromagnetic horns," Proc. I.R.E., vol. 27, pp. 769–780; December, 1939.

[4] Andrew Alford and A. G. Kandoian, "Ultra-high-frequency loop antennae," *Trans. A.I.E.E.*, (*Elec. Eng.*, 1940), vol. 59, pp. 843–848; 1940, and *Elec. Commun.*, vol. 18, pp. 255–265; April, 1940.

[5] M. W. Scheldorf, "FM circular antenna," *Gen. Elec. Rev.*, vol. 46, pp. 163–170; March, 1943.

[6] Jesse B. Sherman, "Circular loop antennas at ultra-high frequencies," Proc. I.R.E., vol. 32, pp. 534–538; September, 1944.

[7] Donald Foster, "Loop antennas with uniform current," Proc. I.R.E., vol. 32, pp. 603–607; October, 1944.

Figs. 7, 8, and 9 show schematic diagrams of the type of loop under consideration. The metallic supporting structure as well as the radiators themselves form part

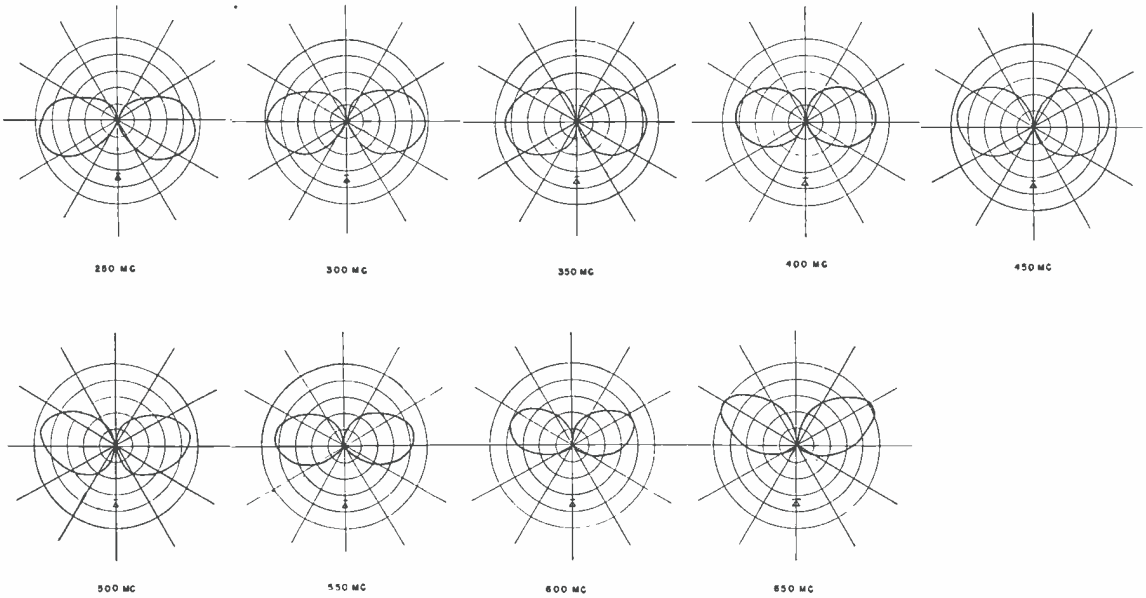

Fig. 4—Vertical radiation patterns of a Discone antenna for a cutoff frequency of 200 megacycles. Radiation patterns measured every 50 megacycles from 250 to 650 megacycles.

of the coaxial feeding system. By proper choice of surge impedance of these two short lengths of line, in the sup-

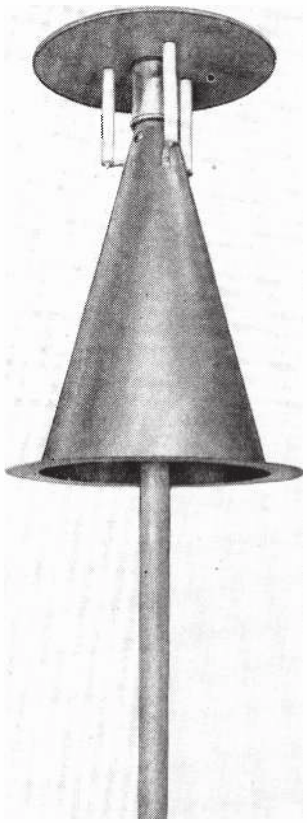

Fig. 5—Discone antenna for cutoff frequency of 90 megacycles.

porting arm and the radiator itself, the desired impedance of 50, 70, or 100 ohms pure resistance may be obtained to match any common type of coaxial trans-

mission line. Fig. 7 shows a single-element design in which the circumference of the loop is in the neighborhood of one-half wavelength or less. Figs. 8 and 9 illustrate multiple-element designs. No limitations, other than practical, exist for the number of elements

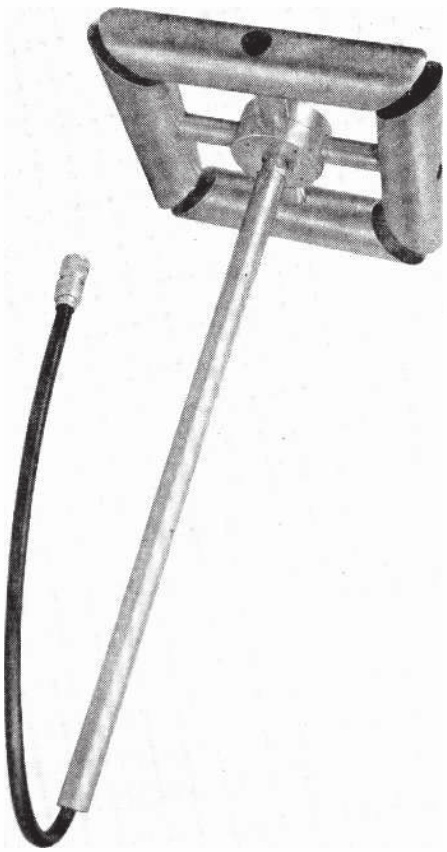

Fig. 6—Coaxially fed loop antenna for 550 megacycles.

making up the loop. Thus, a loop antenna of any diameter may be constructed and the current distribution maintained essentially uniform. The limitation of

diameter, small compared to a wavelength, need not be observed.

The radiation pattern of a loop with substantially uniform current distribution, and with a diameter small compared to a wavelength, is well known. In the plane of the loop the radiation is nondirective. In the plane perpendicular to the loop the radiation varies approximately as cos β, β being the angle measured from the plane of the loop.

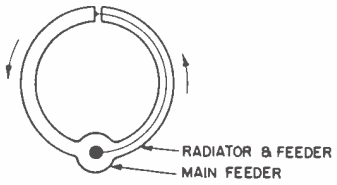

Fig. 7—Schematic diagram of single-element coaxially fed loop. Circumference approximately $\lambda/2$ or less.

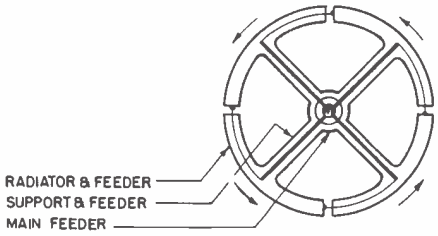

Fig. 8—Schematic diagram of 4-element coaxially fed loop. Circumference approximately 2λ or less.

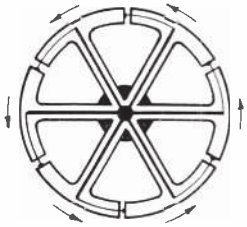

Fig. 9—Schematic diagram of 6-element coaxially fed loop. Circumference approximately 3λ or less.

For loop antennas of any diameter and uniform current distribution, the radiation in the plane of the loop is still nondirective. In the plane perpendicular to the loop, Foster[7] has shown that the pattern is of the form $J_1(\pi d/\lambda \cos \beta)$ where d is the loop diameter to wavelength ratio and J_1 represents the Bessel function of the order unity.

An important consideration in any antenna is the input impedance. At very-high frequencies and ultra-high frequencies, the most practical way of expressing this information is in terms of standing waves on the line feeding the antenna. A typical measurement is shown in Fig. 10. The impedance at the center feed point is inductive below and capacitive above the midoperating frequency of 550 megacycles. The feeding line is a 50-ohm coaxial. Other experimental loops have been constructed giving both more and less bandwidth. In general, however, the bandwidth of a loop antenna cannot be made nearly so wide as a Discone type of antenna.

The loop type of antenna is particularly useful when high-degree directivity is desired in the vertical plane while retaining the omnidirectional pattern in the horizontal plane. This is accomplished by vertical stacking of any desired number of loops.

Fig. 11 depicts two experimental loops built as a pair and spaced approximately one wavelength. The input impedance to the pair is 50 ohms.

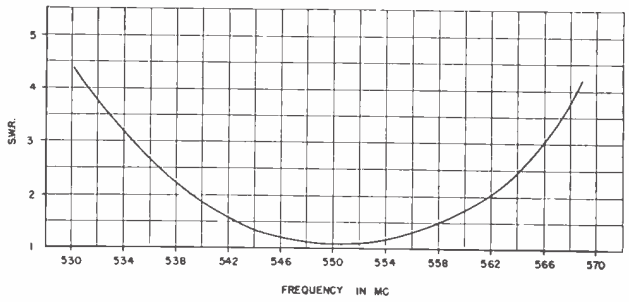

Fig. 10—Characteristic curve of frequency versus standing-wave ratio for a square loop. Four elements of 2-inch cross section; loop diameter, $8\frac{1}{2}$ inches.

Any number of such pairs may be stacked to give a desired amount of power gain. At the junction of the transmission line of any two pairs, however, a 2-to-1

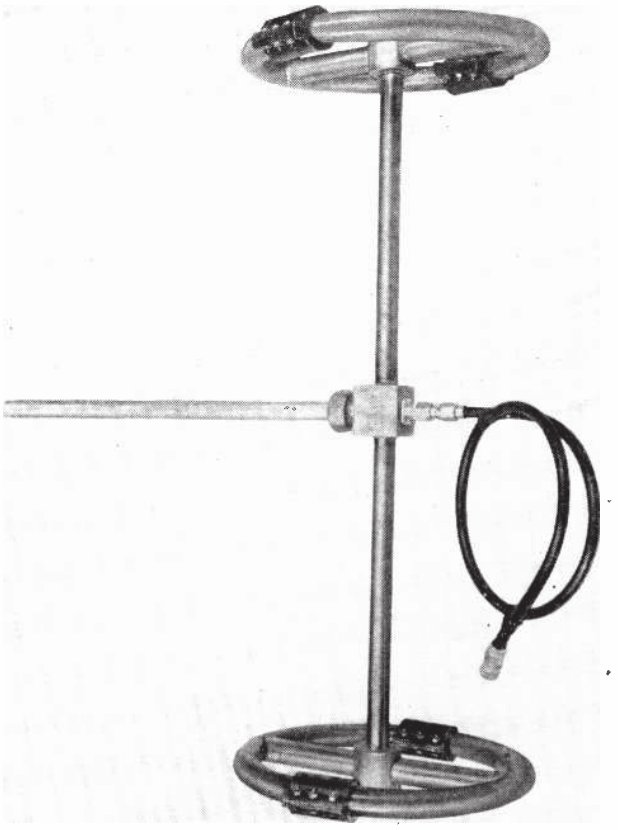

Fig. 11—Vertical stack of two loops with tuning stub.

impedance-correcting network is required to raise the impedance to the line impedance of 50 ohms (or any other desired level). A quarter-wave transformer probably is the most convenient network for this purpose. Fig. 12 shows the schematic of a feeding system for a stack of four loops for frequency-modulation broadcasting

Fig. 13 gives the necessary theoretical data to show what spacings to use between loops and what gains may be expected due to vertical stacking when equal currents are fed to successive loops.

A directive vertical pattern essentially free from minor lobes may be obtained by proper distribution of current between successive stacked loops.[8] However, under these conditions the over-all power gain from a fixed number of loops is reduced.

The characteristics and relative merits of the type of loop under consideration may be summarized as follows:
(a) No balanced feeders are used.
(b) No stubs are needed for matching; hence, the full bandwidth capability of the loop may be realized. A stub may be found desirable, however, to tune the loop, or a group of loops, over a wide frequency range.
(c) No insulator mechanical supports are necessary. Metallic supports are used, rigidly fastened to the mast and radiating members.
(d) Any size loop may be built, with essentially uniform clockwise or counterclockwise current distribution. Loop diameters of several wavelengths are feasible, and for certain applications desirable.

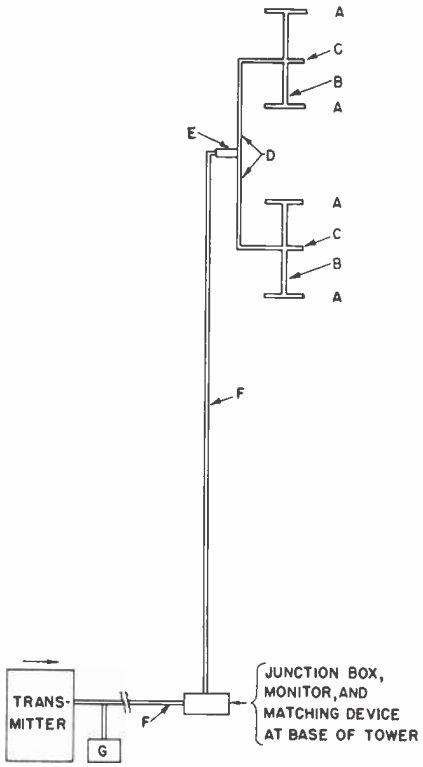

Fig. 12—Transmission line and feeding system for frequency-modulation broadcast antenna.
A = loop antennas
B = 100-ohm coaxial line
C = matching stub to be for operating frequency
D = 50-ohm line
E = quarter-wave 35-ohm line
F = 50-ohm coaxial line
G = pressurizing and air-drying equipment

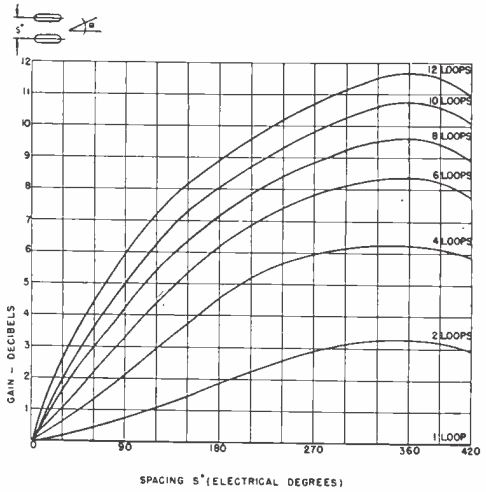

Fig. 13—Gain of linear array of loops vertically stacked.

$$(\beta) = \frac{\sin\left(\frac{ns^\circ}{2}\sin\beta\right)}{\sin\left(\frac{s^\circ}{2}\sin\beta\right)}\cos\beta$$

n = number of loops

$$\text{gain } (db) = 10\log_{10}\frac{1}{\frac{1}{h}+\frac{3}{n^2}\sum_{k=1}^{n-1}(n-k)\left[-\frac{2\cos ks^\circ}{(ks^\circ)^2}+\frac{2\sin ks^\circ}{(ks^\circ)^3}\right]}.$$

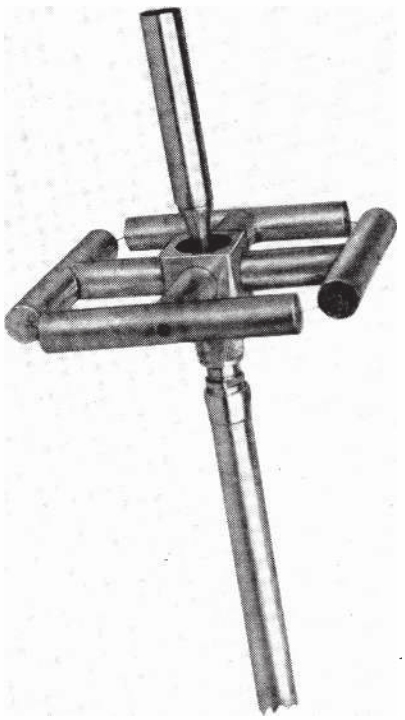

Fig. 14—Type III antenna for an operating frequency of 1200 megacycles.

Type III—"Electric-Magnetic" Dipole

An experimental model of this type of antenna is illustrated in Fig. 14. This particular unit was built for use in the neighborhood of 1200 megacycles.

The "electric-magnetic" dipole consists essentially of a loop radiator of the type previously described, except

[8] A. G. Kandoian, "Ultra-high-frequency technique; radiating systems and wave propagation," *Electronics*, vol. 15, pp. 39–44; April, 1942.

that at the transmission-line junction at the center of the loop, and perpendicular to the plane of the loop, a vertical radiator is added. In effect, it is a combination of an "electric" and a "magnetic" dipole.

The radiation pattern of a horizontal loop, with a diameter of the order of $\lambda/2$ or less, is substantially the same as that of a vertical dipole. The only difference in the radiated field is in polarization. Thus, at every point in space equal amounts of horizontal and vertical polarization will be obtained, if the available power is equally divided between the loop and the dipole.

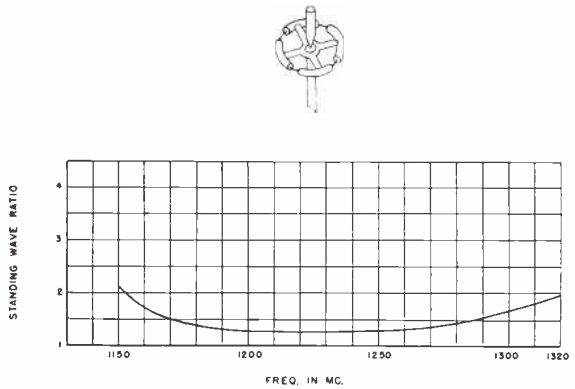

Fig. 15—Curve showing the standing-wave ratio versus frequency for the loop-dipole combination shown at top.

Control of the relative phase and amplitude of currents in the dipole and the loop is, of course, possible; and hence, any type of polarization desired can be produced; i.e., horizontal, vertical, circular, or the most general case, elliptical.

It is not difficult to demonstrate experimentally that at any point around such a transmitting antenna one can achieve a field strength independent of the orientation of the receiving dipole, provided that the receiving dipole is kept perpendicular to the direction of propagation.

In Fig. 15 is shown the mismatch-versus-frequency characteristic of an antenna of this type for operation in the neighborhood of 1200 megacycles. Fig. 16 shows another such experimental antenna for use around 350 megacycles.

In ultra-high-frequency communication networks where considerable fading may exist due to changes in the medium of propagation, this type of antenna will probably prove very useful. In cases of severe fading the probabilities are that both horizontal and vertical components of the electric field will not vary at the same rate and at the same time, since they are affected differently by the reflecting medium between the transmitter and receiver. Considerable improvement, therefore, should be experienced in reducing the over-all fading by the use of such a radiator, or a combination of such radiators in an array.

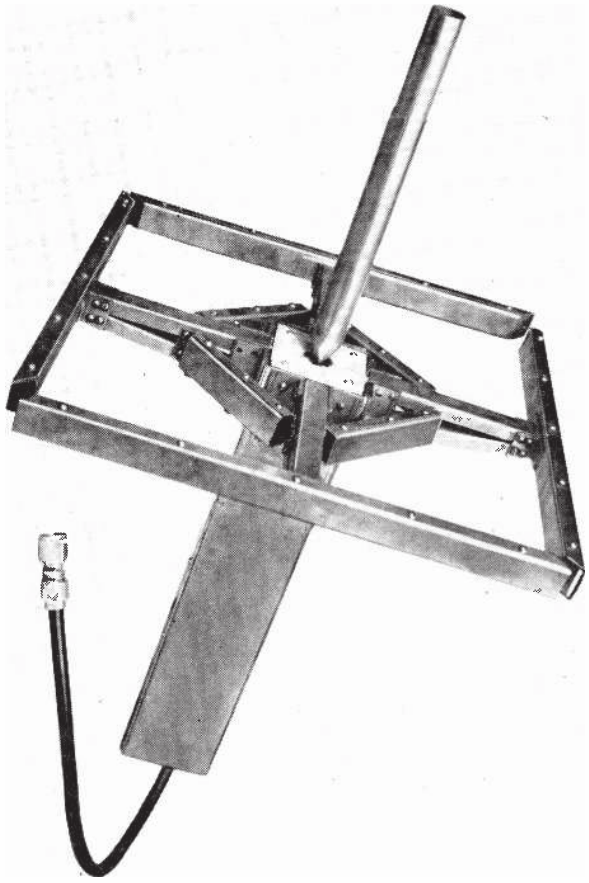

Fig. 16—Type III antenna for an operating frequency of 350 megacycles.

In addition, this type of radiator is particularly well suited for illuminating a large reflecting surface such as a paraboloid in a highly directive antenna system.

A possible important application of the "electric-magnetic" dipole is in the field of very-high-frequency and ultra-high-frequency broadcasting where the relative merits of horizontal as against vertical polarization have been under discussion for some years. If circular polarization were used at the transmitting end, it would permit the use of either a vertical or horizontal dipole at the receiving end, depending on convenience or architectural acceptability. The more particular listener would, of course, tend to orient his dipole to obtain the best signal-to-interference ratio, if there is any interference.

Whether any substantial improvement of performance would result in over-all reception can be determined only after field tests.

Decibel Conversion Chart*

ROBERT C. MIEDKE†, ASSOCIATE, I.R.E.

Summary—A decibel conversion chart has been designed for versatility and simplicity of use. This chart gives decibels directly from any two values of voltage, current, or power. It has two ranges; the lower range (scales *A*, *C*, and *E* of Fig. 1) are for voltage, current, or power ratios up to 10 to 1 and the extended range (scales *B*, *D* and *F*) are for voltage, current, or power ratios up to 10^6 to 1.

SEVERAL examples explaining the use of the decibel conversion chart are as follows:

(1) Assume a voltage ratio of 2.4 to 1.2. This voltage ratio in decibels is found by drawing a line from 1.2 on scale *A* to 2.4 on scale *E* passing through the decibel voltage scale *C* at 6 decibels. This can also be

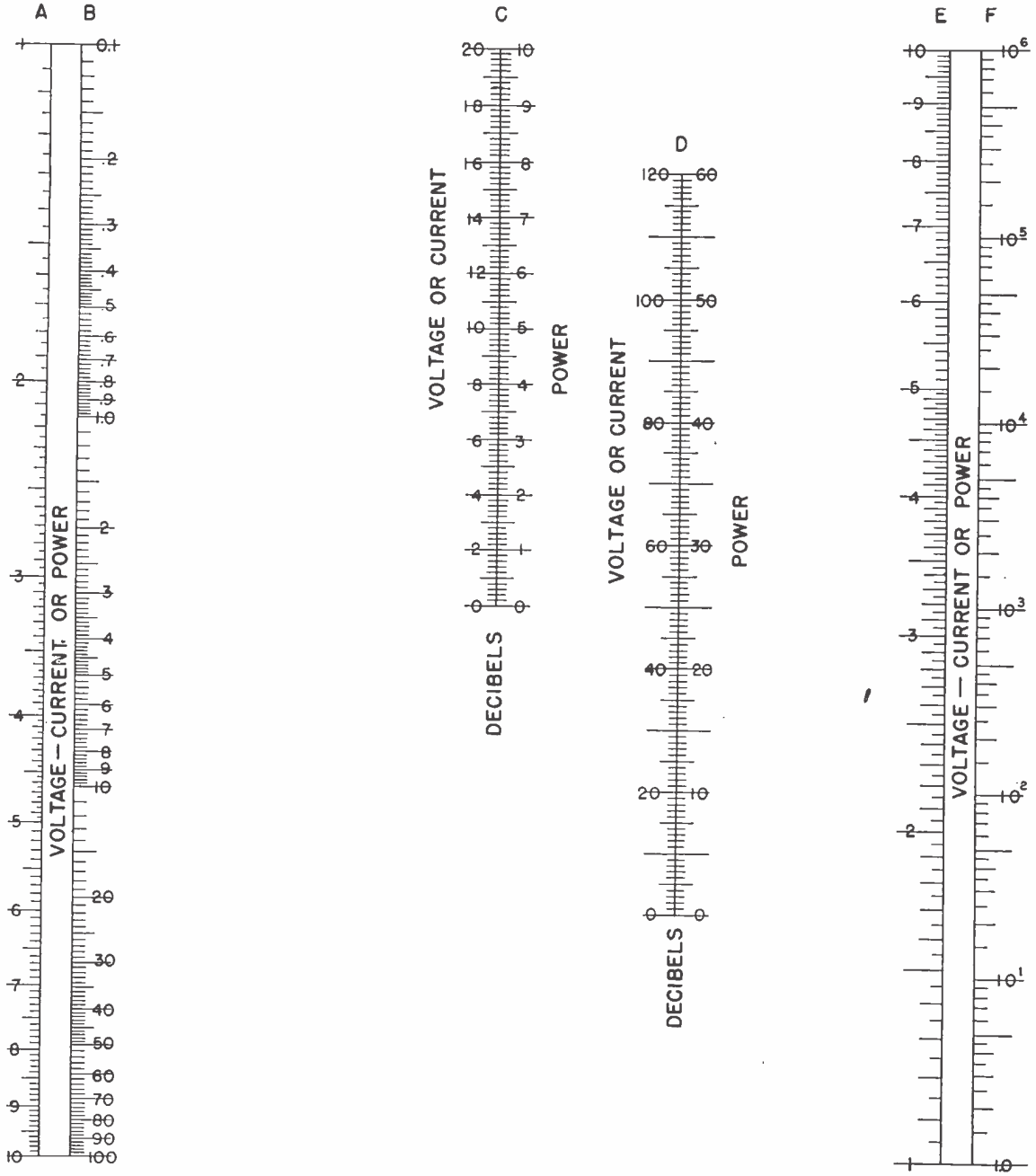

Fig. 1—Chart for converting current or power ratios to decibels.

* Decimal classification: R084. Original manuscript received by the Institute, September 24, 1945; revised manuscript received, November 5, 1945.

† Naval Research Laboratory, Washington, D. C.

found on scales *B*, *D*, and *F;* however, the decibel scale *D* is not expanded so much as the decibel scale *C* and cannot be read as accurately.

(2) Assume a voltage ratio of 1200 to 1.2. This voltage ratio in decibels is found by drawing a line from 1.2 on scale *B* to 1200 on scale *F* passing through the decibel scale *D* at 60 decibels.

(3) Assume a power ratio of 580 to 320. This power ratio in decibels is found by drawing a line from 3.2 on scale *A* to 5.8 on scale *E* (the ratio of 580 to 320 is the same as 5.8 to 3.2) passing through the decibel scale *D* at 2.6 decibels.

From the above examples it will be noted that the smaller value of any ratio will always be located on scale *A* or *B* and the larger value will always be located on the respective scale *E* or *F*. Also, the decibels corresponding to ratios of less than 10 to 1 can be found on either set of scales; however, it is preferable to use scales *A*, *C*, and *E* as the decibel scale *C* is expanded and can be read with greater accuracy.

Allied Military Government and Allied Commission in Italy

An interesting 125-page report entitled: "Review of Allied Military Government and of the Allied Commission in Italy" has reached the Institute from Italy through the courtesy of Rear Admiral Ellery W. Stone, U. S. Naval Reserve (A'14–M'16–F'24), Deputy President and Chief Commissioner of the Allied Commission since June 22, 1944. The magnitude of the tasks assumed in the temporary control of Italian affairs by the Allied Forces is clearly set forth in historical fashion in the report. The Institute is gratified that one of its leading members has played so constructive a part in a project of such magnitude.

Admiral Stone received the Award of Commander of the British Empire in March, 1945, and in December, 1945, he received the appointment as Knight Commander of the British Empire, the K. B. E.

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Nontechnical Radar Broadcast

One of the first network broadcasts intended to explain for nontechnical listeners the principles and objectives of radar was given on September 6, 1945, in New York City when E. W. Engstrom (A'25, M'38, F'40) Irving Wolff (A'27–F'42), and J. E. Evans of RCA Laboratories and Stanley Parker of the U. S. Navy were interviewed by Miss Mary Margaret McBride. The fundamental principles, underlying the operation of radar and early experiments dating back to 1932, were covered by the RCA Laboratories representatives while Stanley Parker told about some of the actual experiences that he had had at sea with the operation of radar equipment. A short demonstration was given to show how a received radio wave when used in conjunction with a sharp microwave transmitting beam, could be used to show the direction of a reflecting object.

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Cleveland Section

In *Cleveland Engineering*, published weekly by The Cleveland Technical Societies Council, the columns devoted to news of The Institute of Radio Engineers contain two items which are of interest to the entire membership of the I.R.E. Alfred J. Kres (A'39), secretary of the Cleveland Section, reported that a very small percentage of the questionnaire postcards, regarding proposed changes in the name of the Institute, had been returned.

The Cleveland Section subscribed 258 per cent over their quota in contributions to the Building Fund. A book containing the names of all contributors, intended to be kept in the lobby of the new building, went to press about December first.

Electronics in War and Peace

C. N. Kimball (A'34–M'40–SM'43), vice-president in charge of sales engineering for Aireon Manufacturing Corporation, recently spoke before the Advertising and Sales Executive Club of Kansas City on the use of early warning radar, ground control of fighter aircraft, blind bombing, and radar countermeasures in World War II. He directed his audience's attention to the proximity fuze and the recent acceleration of electronic research. The latter part of the speech was devoted to the carry-over value of these devices for peacetime functions, covering the navigational uses of radar and the part the absolute altimeter and terrain indicator will play in the safety of flight. Dr. Kimball mentioned the increase in speed of railway travel due to research in radio applications to railroad communication; industrial heating of plastics; uses of high-frequency radiation for cooking and heating applications; development of instruments to be used in the meat industry for determining humidity, frosting, and defrosting; and electronic instruments used in sorting, counting, measuring, oil prospecting, and color comparison.

It was pointed out that there exists an electronic solution or electronic aid for nearly every operation encountered in the course of manufacturing, packaging, or distributing, with the resultant increased safety, comfort, and leisure for the public.

Our New Home

BY AUTHORIZATION of the Board of Directors, The Institute of Radio Engineers has now purchased a building for its home. The Institute has acquired the Brokaw mansion on the northeast corner of Fifth Avenue and 79th Street in New York City. This building faces 79th Street, and is located in an extremely attractive residential neighborhood. It is only a block from the Metropolitan Museum of Art, which is diagonally across Fifth Avenue from the building.

The building is of chateau design, faced with gray granite and with steeply sloping tile roofs. It was constructed in 1889 for Mr. Brokaw, by Rose and Stone, architects. It has four stories, attic, basement, and cellar. The main body of the building is about 47×81 feet. It stands on a lot 51 feet 2 inches on Fifth Avenue and 110 feet along 79th Street. It faces south, and has a spacious yard on the easterly side of the building and open courtyards in front and on the Fifth Avenue sides, which spaces are in lawn. Since it does not occupy the whole lot, it is accessible to sunlight on three sides.

The building was purchased for $200,000 which is believed to be comparable with, or even less than, the value of the land. The mansions of the nineties and nineteen hundreds are being gradually sold. They are then torn down or converted to other uses, because of changes in living habits of the people who could afford to live in them. The property acquired by the Institute could be purchased for what is considered a justified amount because of a complicated ownership situation of a type which does not inspire real estate agents to devote much effort toward its sale, nor attract the speculator who is interested in acquiring property quickly at an opportune moment. Negotiations with three parties and court approval were necessary to complete the transaction.

The Board of Directors at its April, 1945, meeting instructed the Office Quarters Committee to begin negotiations toward the purchase of the property. The deeds were signed and the property

became ours on December 28, 1945.

The building from the exterior is one of the most attractive structures in that part of the city. It is well constructed throughout. Naturally, it will require some changes and alterations to suit it to the purposes of the Institute. However, these changes and alterations are materially less than would be necessary for many other buildings which the Committee seriously considered.

The Office Quarters Committee spent a year and a half searching for a structure considered suitable as a home for the Institute. At the start of this search there was available only a relatively small amount of money in surplus funds of the Institute, and the buildings available then within that limit were few and far between. None was considered a suitable permanent home for the Institute. Serious consideration was given to purchasing one as a temporary home because of the extremely pressing need for more space and the difficulty of finding rentable space in the city.

The Office Quarters Committee in its search inspected dozens of buildings of all kinds including ex-clubs, small office buildings, and many old mansions, and the members picked up on their faces, hands, and clothing considerable dust that may not have been disturbed since the eighteen nineties. After this search had progressed for well over six months, the Office Quarters Committee recommended that the Board approve a campaign to raise a building fund without waiting to have in mind a particular building that they desired to purchase. To have bound themselves to purchase a building before starting the drive for the fund would have involved risking a considerable portion of the Institute's reserves, and the Board wisely would not proceed on this basis. No "superbargain" was found that justified such a plan. It was believed that possible donors would be as willing to donate funds toward the purchase of a building to be selected later as to give funds to buy a particular building picked beforehand. In the latter half of 1944, therefore, the intensive search for a building was temporarily abated while plans were gotten under way to start the building-fund drive. Early in 1945 when the donations being received indicated that the goal desired likely would be reached, the Committee invited the Board to inspect the most promising buildings at prices falling within the range of the expected building fund. The Board was unhesitatingly in favor of the building which has just been purchased.

The Board and the Committee gave much attention and thought to the matter of acquiring a home which would be nearer the center of New York City, that is, nearer the railway stations, large hotels, and the three subway lines that tend to serve the center of Manhattan so thoroughly. Suitable and appropriate buildings, however, were very scarce and their price was very high. It would cost the Institute $100,000 to $200,000 more to acquire an equivalent home convenient to all the transportation centers than to purchase the building it has acquired. Neither the Committee nor the Board was persuaded that this extra expense was justified. The Institute staff will be the persons who are traveling to and from the building every working day. Such groups of long-term employees usually adjust their home locations to the site of their work. Committee Members in holding Committee meetings will travel to and from the building occasionally, and the Board will do so once each month or less frequently. Inquiry as to whether institutions located somewhat outside of the central business district find themselves handicapped by such locations led to the reply that they did not. People from outside of the city coming into the city usually do not find it any more difficult to reach a moderately outlying building by a taxicab than a more near-by one. Local commuting members who develop the habit of catching certain trains home are the ones who prefer always to be within a short distance of their railway terminal, and who particularly stressed their wish for what would be for them a more convenient location. The Committee and the Board, therefore, after considering all factors, felt they could not justify the purchase of a home in the highly expensive central business part of the city but that the location which they have secured will be satisfactory.

The building is a six-minute walk from the 77th Street stop on the Lexington Avenue subway and only about two more minutes' walk from the 86th Street stop, which is an express station. Fifth Avenue buses pass by the building on Fifth Avenue and there is a bus line running completely across 79th Street and passing the building. There seems to be a goodly supply of taxicabs passing up and down Fifth Avenue all the time.

The building has ample room for Committee meetings, Board meetings, and other normal activities. No attempt was made to find a building which could serve as a meeting place for a large group of members. The cost of such a building would not be justified as such meeting rooms would be used by the Institute only one or two days per month. Meetings of the New York Section will continue to be held either in the Engineering Societies Building on 39th Street or in other auditoriums in the city.

The Committee now is making detailed plans for alterations and decoration of the building for Institute purposes and to meet present safety regulations. It is not known when these alterations will be completed due to the difficult building-construction situation in the city. Every effort will be made to have the remodeling done as soon as possible in order that the staff, which is now divided between two locations, can be brought together again.

A photograph of the exterior of the building is to be found in this issue of the PROCEEDINGS. It is planned to publish in later issues the plans of the building, and photographs of parts of the interior. It is thought that the new headquarters of the Institute will be exceptionally attractive in appearance, and that particularly efficient operation of the work of the Institute can be carried out by the staff in the carefully planned new quarters. It is expected that the new building will have a homelike and welcoming atmosphere so that the visiting members will at last find commodious and cheerful I.R.E. quarters in which they can meet the staff and their fellow members and comfortably conduct whatever activities they have planned.

R. A. Heising, *Chairman*
Office Quarters Committee

Winter Technical Meeting

January 23, 24, 25, and 26, 1946

SUMMARIES OF TECHNICAL PAPERS

No papers are available in preprint or reprint form nor is there any assurance that any of them will be published in the PROCEEDINGS OF THE I.R.E. AND WAVES AND ELECTRONS, although it is hoped that many of them will appear in their pages.

CONSIDERATION OF FREQUENCY, POWER, AND MODULATION FOR A LONG-RANGE RADIO NAVIGATION SYSTEM

P. R. ADAMS
(Federal Telecommunication Laboratories, Inc., New York, N.Y.)

The general suitability of various types of radio transmission are examined with respect to the requirements of a long-range aerial-navigation system. By long-range navigation is meant, primarily, transoceanic navigation over distances of the order of 1500 miles.

The characteristics of short waves and long waves are separately and thoroughly analyzed with the help of considerable data which have been tabulated for this purpose. Data on other important factors are also considered, such as on signal field strength, in particular, for transmission below 300 kilocycles, also on atmospheric noise intensities, and on antenna radiating efficiency. A certain number of conclusions are obtained from these discussions. Modulation and other problems such as corona effect are also considered.

PHASE AND FREQUENCY MODULATION—A NEW METHOD

ROBERT ADLER
(Zenith Radio Corporation, Chicago, Ill.)

AND

F. M. BAILEY AND H. P. THOMAS
(General Electric Company, Syracuse, N. Y.)

The design of frequency-modulation transmitters has been simplified and their performance improved by the development of a new phase-modulator tube. In a concentric structure of conventional dimensions, a radial electron stream is shaped into a wave-like pattern which progresses continuously around the cathode. The development of the tube is reviewed. A description is also given of a commercial frequency-modulation broadcast transmitter making use of this tube together with a discussion of the design features involved.

ANTENNA FOR FREQUENCY-MODULATION STATION WGHF

ANDREW ALFORD
(Consulting Engineer, Cambridge, Mass.; formerly, Antenna and Direction-Finder Division, Radio Research Laboratory, Harvard University, Cambridge, Mass.)

An antenna of a new type is described. The radiation is horizontally polarized and essentially omnidirectional. One radiating element gives considerable gain over a dipole in the vertical plane. Design data and test results are discussed.

BROAD-BAND ANTENNAS AND DIRECTION-FINDING SYSTEMS FOR VERY HIGH FREQUENCIES

ANDREW ALFORD
(Consulting Engineer, Cambridge, Mass.; formerly, Antenna and Direction-Finder Division, Radio Research Laboratory, Harvard University, Cambridge, Mass.)

AND

J. D. KRAUS, A. DORNE, AND J. CHRISTENSEN
(Formerly, Antenna and Direction-Finder Division, Radio Research Laboratory, Harvard University, Cambridge, Mass.)

Methods have been developed to obtain broad-band antenna operation with low standing-wave ratio for frequency ranges employed in radar. The description of these methods includes directional antennas, antennas with circular polarization, slot antennas, nondirectional antennas, and also direction finders giving instantaneous visual presentation of direction for the same frequencies. These direction finders are usable over wide frequency ranges without any antenna adjustments and have a pickup sensitivity comparable to or exceeding that of a half-wave dipole. Examples of homing devices for use on airplanes are given.

DESIGN OF A SMALL SIZE HIGH-VOLTAGE RECTIFIER, TYPE 1Z2

GEORGE BAKER
(National Union Radio Corporation, Newark, N. J.)

The new factors in the design of a small-size, low-current rectifier tube for operation at several kilovolts are considered. The filament must withstand large mechanical forces produced by the electric field. The anode is shaped and processed to minimize cold field emission which, if uncontrolled, would result in large reverse current and high-velocity electrons striking the glass. The dielectric losses and leakage currents in the glass must be kept within limits.

MAGNETIC RECORDER AS AN ADJUNCT TO THE HOME RECEIVER

S. J. Begun
(Brush Development Company, Cleveland, Ohio)

BASIC PRINCIPLES OF UNDERWATER SOUND-EQUIPMENT DESIGN

Captain R. Bennett
(U. S. Navy, Bureau of Ships, Navy Department, Washington, D. C.)

The general subject of sound navigation and ranging is discussed in outline with some emphasis on the historical side of this little-known field.

The use of sonic and supersonic echo ranging and detection equipment for location of submarines is discussed briefly with special emphasis on the general principles of systems. Some of the special problems in this field of general interest are presented for information and possible study.

ELECTRONICS IN NAVAL WARFARE

Captain R. Bennett
(U. S. Navy, Bureau of Ships, Navy Department, Washington, D. C.)

A general survey of the use of electronic equipment in naval warfare is given with special emphasis on the progress made during the war. An attempt is made to show the interrelation of military uses of equipment with commercial uses. The effects of standardization and lack of it are indicated as they apply to the military and commercial fields. In this connection, some of the circuit developments made during the war are discussed briefly. This paper is nonmathematical.

NAVAL AIRBORNE RADAR

Captain L. V. Berkner
(U. S. Navy, Bureau of Aeronautics, Navy Department, Washington, D. C.)

Development of airborne microwave radar with improved indication gave enormous impetus to aircraft applications and produced advanced types of air to air interception, high- and low-altitude bombing, reconnaissance, submarine search, and many specialized applications. Several types of airborne radar and auxiliary devices are discussed and illustrated, including considerations of design and utilization problems. Limitations of advantages of airborne radar as a solution to future aircraft problems are briefly considered.

TEST EQUIPMENT AND TECHNIQUES FOR AIRBORNE RADAR FIELD MAINTENANCE

Captain E. A. Blasi and G. C. Schutz
(Radar Laboratory, Air Technical Service Command, Dayton, Ohio)

This paper discusses the various testing methods, techniques, and equipment that are used for the field maintenance of airborne radar systems. Techniques used in the measurement of frequency, power, and receiver sensitivity are outlined, as well as measurements of performance characteristics peculiar to airborne radar equipment. The specially designed instruments required for field maintenance and unique procedures devised to accomplish the measurement of radar performance are described.

FIELD INTENSITIES BEYOND LINE OF SIGHT AT 45.5 AND 91 MEGACYCLES

C. W. Carnahan, N. W. Aram, and E. F. Classen
(Zenith Radio Corporation, Chicago, Ill.)

This paper presents the results of a field-intensity monitoring project initiated by the Federal Communications Commission during the summer of 1945. Signal strengths from WMFM, a frequency-modulation broadcast transmitter at 45.5 megacycles, and an experimental 91-megacycle transmitter, both located at Richfield, Wisconsin, were continuously monitored for a period of two months at Deerfield, Illinois, a distance of about 80 miles. The data are analyzed in terms of the average field strengths at the two frequencies, and individual characteristics, such as the range and prevalence of fading and diurnal variation of average field strength. Comparison is made with field strengths predicted from Federal Communications Commission curves, and the ratio of the 91-megacycle field strength to that at 45.5 megacycles is found to be considerably lower than expected.

TWO NEW MINIATURE TUBES FOR FREQUENCY-MODULATION CONVERSION

R. M. Cohen, R. C. Fortin, and C. M. Morris
(RCA Victor Division, Harrison, N. J.)

The use of a new miniature converter tube and a new miniature radio-frequency amplifier tube in the headend unit of a frequency-modulation receiver covering the 88- to 108-megacycle band is described. The unit employs a radio-frequency stage, a converter stage, and two intermediate-frequency stages. Pertinent data covering construction and performance including circuit constants, stage gain, over-all gain, signal-to-noise ratios, image rejection, and oscillator-frequency drift are presented.

MICROWAVE MAGNETRONS

GEORGE COLLINS
(Radiation Laboratory, Massachusetts Institute of Technology, Cambridge, Mass.)

A brief historical introduction reviews the wartime development and applications of microwave magnetrons. A review of the principles of operation and basic theories, as far as they are known, is presented, and a consideration of design principles, such as voltage and wavelength scaling and cathode problems, follows. Slides illustrating the construction of magnetrons designed for specific purposes are shown and actual operating conditions and characteristics given. A review of certain important characteristics of microwave magnetrons, both advantageous and otherwise, proceed some concluding remarks on special continuous-wave magnetrons suitable for communication purposes.

DESIGN OF COMMUNICATION RECEIVERS FOR THE NAVAL SERVICE WITH PARTICULAR CONSIDERATION TO THE VERY-HIGH-FREQUENCY AND ULTRA-HIGH-FREQUENCY RANGES

T. MCL. DAVIS
(Naval Research Laboratory, Washington, D. C.)

Consideration is given to the unusual conditions under which naval communication receivers must function, the ideal receiver to meet these conditions, and the compromises which have been accepted in the interest of economy of space and weight, simplicity of operation and maintenance, and others which must be accepted due to limitations imposed by tube and circuit characteristics at the present state of developmental progress. The influence upon design as dictated by allocated channel spacing is discussed. The consideration is directed chiefly to the 100- to 400-megacycle band.

DEVELOPMENT IN RADIO SKY-WAVE PROPAGATION RESEARCH AND APPLICATIONS DURING THE WAR

J. H. DELLINGER AND NEWBERN SMITH
(National Bureau of Standards, Washington, D. C.)

During the war, there were both a great and continuing improvement in world-wide coverage of ionospheric observing stations and development of rapid, simplified techniques for applying ionospheric data to military operational problems. The major aspects of the world-wide radio-propagation program, developed during the war, are described in this paper, some of which are geomagnetic "longitude effect" in the ionosphere, world-wide study of atmospheric radio noise, methods for calculating sky-wave field intensities, ionospheric-storm forecasting, effects of ionosphere on direction-finder indication, new frequency-allocation and -selection methods, and rapid dissemination of predictions and forecasts to the Allied Armed Services.

NAVY RADIO AND ELECTRONICS DURING WORLD WAR II

COMMODORE JENNINGS B. DOW
(U. S. Navy, Bureau of Ships, Navy Department, Washington, D. C.)

A decisive factor in our victories over the Axis Powers in World War II was the superiority of our radio-communication systems and the electronic equipment used in radar, sonar, loran, fire control, countermeasures, and ordnance. The paper deals with the vast expansion of the electronic industry to supply needed equipment, the organization of the Navy for research and development, procurement, installation and maintenance of the equipment. Statistical data are introduced to show the magnitude of the electronic-material problem, and the effort required to equip our vast fleet and its air arm with modern electronic apparatus in all categories.

GENERATION OF CONTINUOUS-WAVE POWER AT VERY HIGH FREQUENCIES

W. G. DOW, J. N. DYER, W. W. SALISBURY, AND E. A. YUNKER
(Radio Research Laboratory, Harvard University, Cambridge, Mass.)

Techniques for the generation of continuous-wave power at high frequencies have advanced greatly in recent years, both with respect to the amount of power that can be generated and the frequencies that can be reached. This paper describes a number of oscillator and amplifier techniques for the generation of continuous-wave power in the range of frequencies used by radar. These power sources are tunable over considerable frequency ranges such as 1.5 to 1, and can be modulated over relatively wide frequency bands. Arrangements employed include open-wire resonant lines with conventional tubes, concentric oscillators employing parallel-plane triodes, resonatrons, and magnetrons. Powers range from 10 watts upward, depending on the tubes employed, and the frequencies. The art has been advanced sufficiently to permit generation of at least 1 kilowatt of continuous-wave power up to the lower frequencies used in microwave radar, and powers as great as 30 kilowatts can be obtained at somewhat lower frequencies.

MICROWAVE CONVERTERS

C. F. EDWARDS
(Bell Telephone Laboratories, Inc., New York, N. Y.)

Microwave converters using point-contact silicon rectifiers as the nonlinear element are discussed with particular emphasis on the design of the networks connecting the rectifier to the input and output terminals.

Several converters which have been developed during recent years for use at wavelength between 3 and 30 centimeters are described. Some of the effects of the impedance-frequency characteristic of the networks on the converter performance are discussed.

IMPROVED CATHODE-RAY TUBES WITH METAL-BACKED LUMINESCENT SCREENS

D. W. Epstein and L. Pensak
(RCA Laboratories, Princeton, N. J.)

Considerably improved cathode-ray tubes result from the application of a thin metallic layer on the beam side of the luminescent screen. Observations and measurements of such tubes show the advantages of increased light output, improved contrast, elimination of secondary-emission difficulties, and, under appropriate conditions, the elimination of ion spot.

SOME TECHNICAL DEVELOPMENTS IN LIGHT-WAVE COMMUNICATIONS

Commander J. M. Fluke and Lieutenant (j.g.) N. E. Porter
(U. S. Naval Reserve, Bureau of Ships, Navy Department, Washington, D. C.)

The purpose of this paper is to present and describe some of the recent technical advances in methods and components utilized in light-wave-communication devices. Reasons for exploitation of communication possibilities in the so-called light-wave portion of the spectrum are initially discussed, and some comparison is made with other communication methods. Included in this discussion, also, are the features of some of the new types of light-energy radiators, filter developments, converter tubes, highly sensitive receiving elements, and the associated electronic power supply and amplifying equipment.

A MEDIUM-POWER TRIODE FOR FREQUENCIES ABOUT 600 MEGACYCLES

S. Frankel and J. J. Glauber
(Federal Telecommunication Laboratories, Inc., New York, N. Y.)
and
J. Wallenstein
(Federal Telephone and Radio Corporation, Newark, N. J.)

A tube is described which was originally designed for pulse operation to deliver approximately 50 kilowatts peak power output at 600 megacycles with good efficiency.

Design considerations are discussed which include, as the most important factor, problems of transit time, peak emission, cooling, and circuit properties of the internal tube structure.

A detailed description of this tube structure is given which includes design considerations of the electrodes, operating conditions, and static characteristics. Uniformity of characteristics is also discussed.

Methods of testing and using the tube as an oscillator, amplifier and frequency multiplier are described and the results obtained are given. These results include data and curves of power output versus frequency; efficiency versus frequency; power gain as an amplifier and multiplier; and life-test results.

THE ROLE OF ATMOSPHERIC DUCTS IN THE PROPAGATION OF SHORT RADIO WAVES

J. E. Freehafer
(Radiation Laboratory, Massachusetts Institute of Technology, Cambridge, Mass.)

Experience gained during the war has shown that strong fields, at frequencies greatly exceeding the penetration frequency of the ionosphere, are often observed at several times the horizon distance. Experimental and theoretical investigations in this country and in England indicate that these effects are associated with the presence of layers in the troposphere in which the vertical gradient of refractive index exceeds numerically the reciprocal of the earth's radius. Under these conditions a duct is former which for sufficiently high frequencies both reduces the rate at which the field is attenuated with range and also disturbs the normal height-gain effect.

A SPECTRUM ANALYZER FOR MICROWAVE PULSED OSCILLATORS

F. J. Gaffney
(PIB Products Company, Brooklyn, N. Y.; formerly Radiation Laboratory, Massachusetts Institute of Technology, Cambridge, Mass.)

A spectrum analyzer is described which utilizes a sharply tuned receiver whose response frequency is swept across the frequency spectrum to be analyzed at a rate slow compared to the pulse recurrence rate. The receiver output pulses are displayed on the screen of a cathode-ray oscilloscope whose horizontal sweep is synchronized with the variation of receiver response frequency. The envelope of these pulses represents the Fourier transform of the pulsed oscillator output. The distortion produced by the finite bandwidth of the receiver is analyzed. Design details of the radio-frequency input plumbing are discussed.

ELECTRICAL CHARACTERISTICS OF QUARTZ-CRYSTAL UNITS AND THEIR MEASUREMENT

W. D. George, M. C. Selby, and R. Scolnik
(National Bureau of Standards, Washington, D. C.)

An investigation of methods of accurately measuring the performance characteristics of two-terminal quartz-crystal units is presented. Relative merits and limitations of these methods are listed and forms of presentation of performance characteristics are indicated. Some observations of crystal-unit behavior, most useful to the radio-and-electronic engineer, are given. These may be interpreted and predicted on the basis of the performance characteristic curves suggested. It is believed that a practical approach is described whereby relatively simple measuring apparatus may be used in studying and standardizing those constants and characteristics that specify the quartz-crystal unit in itself apart from any external circuits with which it may be applied.

TELEVISION IN THE ULTRA-HIGH FREQUENCIES

Peter C. Goldmark
(Columbia Broadcasting System, New York, N. Y.)

The Columbia Broadcasting System ultra-high-frequency television system and results of recent tests are described and considerations of color in television discussed.

MICROWAVE TRIODES ADAPTED TO MODERN USAGE

Everett M. Goodell
(Sylvania Electric Products, Inc., Emporium, Pa.)

A new series of planar-grid triodes has been developed which is adaptable both to pulse and continuous operation at microwave and lower frequencies. Special features incorporated into the mechanical design permit quick changes and adaptability to a wide variety of usage.

A NEW SYSTEM OF ANGULAR VELOCITY MODULATION EMPLOYING PULSE TECHNIQUES

James F. Gordon
(Bendix Radio Division, Baltimore, Md.)

A frequency-modulation system is described in which a crystal-controlled pulse triggers a multivibrator. This pulse establishes a reference time for the system. The asymmetry of the multivibrator cycle varies with modulation. Clipping the reference pulse and differentiating the intelligence pulse which is generated at the cross-over point of the multivibrator cycle produces a source of time-modulated intelligence. These pulses are used to control the phase of a continuous-wave carrier.

LINEAR SERVO THEORY

R. E. Graham
(Bell Telephone Laboratories, Inc., New York, N. Y.)

The servo system is presented as a feedback circuit. Typical components of electromechanical circuits are described in homogeneous terms by means of a conventional analogy. The nomenclature of frequency analysis is used to describe the servo circuit as a transmission system.

The problems of linear servo design are discussed in the language of electrical-circuit feedback theory. A simple logarithmic frequency plot is found adequate for most design considerations. Exact and approximate methods for calculating dynamic errors in follow-up systems are described, and a discussion is given of the interrelations between input signal, dynamic error, transient response, and noise vulnerability.

Linearization of motor-drive systems by use of local velocity feedback and pre-equalization of the input signal to reduce over-all error are described.

AIRBORNE RADAR EQUIPMENT FOR AIRCRAFT INTERCEPTION

Major F. L. Holloway, Captain R. P. Burrows, and J. E. Keto
(Radar Laboratory, Air Technical Service Command, Dayton, Ohio)

This paper describes some of the outstanding airborne radar equipments and systems developed during the war for the radar-bombing operations of the Army Air Forces. Technical characteristics and requirements of such equipment are presented. Problems introduced by the technical and operational aspects of radar bombing are discussed as well as the effect of such problems on the design of the subject equipment.

TUNABLE RECEIVERS FOR VERY HIGH FREQUENCIES

G. E. Hulstede, J. M. Pettit, H. E. Overacker, K. Spangenberg, and R. R. Buss
(Radio Research Laboratory, Harvard University, Cambridge, Mass.)

Developments have greatly advanced receiver techniques in the direction of obtaining tunability, good

sensitivity, and wide frequency coverage at increasing high frequencies. This paper describes techniques that have been employed in a line of receivers that give continuous coverage of 10,000 megacycles. The most advanced of these equipments have high image rejection even at microwave frequencies, have single-dial control, a sensitivity reasonably close to the theoretical ultimate, and are tunable over frequency ranges of approximately 2 to 1 or more.

THE THEORY AND APPLICATION OF THE RADAR BEACON

CAPTAIN R. D. HULTGREN AND L. B. HALLMAN, JR.
(Watson Laboratories, Red Bank, N. J.)

Part I discusses the general theory underlying the operation of radar beacons. The various components of a typical beacon, such as the receiver, discriminator, modulator, coder, and transmitter, are discussed in some detail. System considerations such as factors governing choice of operating frequencies, required receiver sensitivity and transmitter power, choice of pulse duration, the cause and effect of delay in the beacon, and type of coding, are discussed. Part II discusses the application of radar beacons to aircraft homing, landing, rendezvous, identification, and airport surveillance. Special types of radar beacon applications such as the Beacon Blind Approach System (BABS), sea rescue devices, and communication aids are discussed in some detail.

THREE- AND NINE-CENTIMETER PROPAGATION MEASUREMENTS IN LOW-LEVEL OCEAN DUCTS

M. KATZIN AND R. W. BAUCHMAN
(Naval Research Laboratory, Washington, D. C.)

In order to check the effect on three- and nine-centimeter transmissions of low-level ducts formed in oceanic air, one-way measurements between a ship and a shore station were made with antenna combinations of various heights. The experimental setup and techniques are described. Meteorological measurements taken from both shore and ship are described, and the variations in duct height and strength discussed. Meteorological and radio measurements inland were made, and the effect of distance back from the shore on meteorological conditions and radio transmission are described. Three-centimeter radar observations were made during the latter part of the project, and the variation of echo amplitude with range of ship target was measured. Analysis of radio and radar measurements is given.

NAVAL WARFARE COMMUNICATIONS PROBLEMS

COMMANDER J. O. KINERT
(U. S. Navy, Naval Operations, Navy Department, Washington, D. C.)

A brief review of problems encountered during the development and growth of amphibious assault techniques is given. How problems were met from point of view of electronic material with an evaluation of available types is discussed. Recommendation for future design is also given.

METAL-LENS ANTENNAS
(With Demonstration)

W. E. KOCK
(Bell Telephone Laboratories, Inc., New York, N. Y.)

A new type of antenna is described which utilizes the optical properties of radio waves. It consists of a number of conducting plates of proper shape and spacing and is, in effect, a lens whose focusing action is due to the high-phase velocity of a wave passing between the plates. Its field of usefulness extends from the very short waves up to wavelengths of perhaps five meters or more. The paper discusses the properties of this antenna, methods of construction, and applications.

TWO MULTICHANNEL MICROWAVE RADIO-RELAY EQUIPMENTS FOR THE U. S. ARMY COMMUNICATION NETWORK

RAYMOND E. LACY
(Coles Signal Laboratory, Red Bank, N. J.)

Radio set AN/TRC-5 and radio set AN/TRC-6 are described whereby the U. S. Army Signal Corps has pioneered in applying the art of microwave techniques to communication equipments in order to provide transportable multichannel radio-relay sets for interconnection with high-grade voice circuits. An explanation is given of radar-type pulse-time-division methods of modulation which eliminate the relatively cumbersome carrier-frequency terminal equipment usually associated with a multiplex system. Audio performance and radiation characteristics are shown which presage a microwave epoch for long-lines communication.

CAPACITANCE-COUPLED WIDE-BAND INTERMEDIATE-FREQUENCY AMPLIFIERS

MERWIN J. LARSEN AND LYNN L. MERRILL
(Stromberg-Carlson Company, Rochester, N. Y.)

The design and performance of capacitance-coupled intermediate-frequency amplifiers is discussed, with

particular emphasis on applications to television receivers. Experimentally obtained curves are presented as an aid in selecting the circuit parameters necessary to produce flat-top frequency response for various operating ranges. The design of capacitance-coupled traps is treated theoretically, and experimental evidence is presented to show the validity of the theoretically predicted results.

A THREE-BEAM OSCILLOGRAPH FOR RECORDING AT FREQUENCIES UP TO 10,000 MEGACYCLES

GORDON M. LEE
(Central Research Laboratories, Red Wing, Minn.)

Transit-time distortion is a fundamental limiting factor in the application of high-speed cathode-ray oscillographs to the recording of high-frequency voltages or fast transients. A three-beam, high-speed, micro-oscillograph is described in which the transit-time reduction in deflection sensitivity is calculated to be but 4 per cent at 3000 megacycles and 40 per cent at 10,000 megacycles. Single-sweep oscillograms of 3000 and 10,000 megacycle oscillations and 10^{-9}-second transients are shown.

CASCADE AMPLIFIER KLYSTRONS

E. C. LEVINTHAL
(Sperry Gyroscope Company, Inc., Garden City, L. I., N. Y.)

The theory of operation of a three-resonator klystron amplifier is discussed for the case of small-signal operation. An analogy between the operation of a cascade amplifier and velocity modulation by a saw-tooth voltage is demonstrated. Some calculated values of tube parameters are given which yield theoretical efficiencies in the neighborhood of 74 per cent. Data are presented which verify the production of greater efficiency for large-signal operation.

ENEMY RADIO AND RADAR EQUIPMENT

LIEUTENANT COMMANDER E. L. LUKE
AND JOHN C. LINK
(Naval Research Laboratory, Washington, D. C.)

ULTRA-HIGH-FREQUENCY TELEVISION RECEIVERS

HAROLD T. LYMAN
(Columbia Broadcasting System, New York, N. Y.)

Combined black-and-white and color television receivers, both in direct-view and projection types, have been developed in the Columbia Broadcasting System laboratories. These receivers operate in the television band between 480 and 920 megacycles with sight and sound on one carrier. Details of circuit design, mechanical layout, and performance data are presented.

APPLICATION OF RADAR TECHNIQUES TO AIRCRAFT FIRE-CONTROL SYSTEMS

MAJOR E. A. MASSA, CAPTAIN I. PAGANELLI, AND
CAPTAIN FRED A. BEST, JR.
(Radar Laboratory, Air Technical Service Command, Dayton, Ohio)

This paper will discuss the basic problems involved in aircraft fire-control systems and the three basic types of radar systems which have been developed to solve these problems. A more detailed description of several of these equipments, including equipments which depart from conventional radar design, will be presented. The advantages which have been gained by the use of radar in this field will be listed and analyzed. A short discussion of future radar fire-control systems concludes the paper.

THE ROLE OF ELECTRONICS IN ANTIAIRCRAFT GUN-FIRE CONTROL

CAPTAIN F. B. MACLAREN
(Ordnance Department, Frankford Arsenal, Philadelphia, Pa.)

During the war, our major caliber antiaircraft equipment advanced from an essentially mechanical system to one employing electronics as a vital part. A detailed description of the circuits involved in associated radar, computer, servomechanism, and proximity-fuze components, compared with equivalent enemy material, will explain the high degree of effectiveness obtained in combat. However, many improvements are still needed in electronic systems to supplement the defense against weapons such as the German V-2 rocket, especially if augmented with atomic power.

SECONDARY-EMISSION CATHODES FOR MAGNETRONS

J. W. MCNALL, H. L. STEELE, JR.,
AND C. L. SHACKELFORD
(Westinghouse Electric Corporation, Bloomfield, N. J.)

A few weeks before Pearl Harbor, an investigation was begun at the Massachusetts Institute of Technology Radiation Laboratory on cathodes for microwave multicavity magnetrons. The cathode used for such tubes was an indirectly heated oxide-coated cathode. It was known that the cathode temperature increased considerably due to back-bombardment by electrons when the magnetron was operated, and, in fact, it was believed that most of the emission current was not of thermionic but rather of secondary origin. Realizing that the electron back-bombardment of the cathode would impose undesirable limitations on the duty cycle and maximum average power at which magnetrons could be operated, it was decided to investigate the feasibility of using a cold secondary-emitting cathode in place of the thermionic one generally used. Since bombardment of the cathode can occur if the magnetron is oscillating, and since the magnetron will oscillate only

if there are electrons available in the cathode-anode space, it is obvious that an auxiliary primary emitter must be provided. This emitter is required to supply, however, only enough current to initiate oscillations in the magnetron. At the Radiation Laboratory, many different materials were used as secondary emitters, including beryllium, aluminum, nickel-barium alloy, thorium, and silver-magnesium alloy.

At the beginning of 1943, this project was discontinued at the Radiation Laboratory and was taken up in the Westinghouse Lamp Division Research Department. The work was directed along several lines including investigations of activation processes, methods of cooling the secondary-emitting cathode, investigations of several more materials, testing at higher duty cycles, studies of the effects of heating, measurements of the secondary emission yield of the surface, and correlations of these yield measurements with the maximum peak emission currents obtainable for various voltages and states of activation.

FREQUENCY ALLOCATIONS

COMMANDER PAUL D. MILES
(Federal Communications Commission, Washington, D. C.)

A brief review of international and domestic frequency-allocation regulation is given, followed by a description of the steps taken in the past two years by the United States to prepare for the next international telecommunications conference. Consideration is given to new radio services which must be anticipated, their probable effect upon future allocation tables, and improved techniques which must be exploited to insure the accommodation of these services in the spectrum.

PROBLEMS ASSOCIATED WITH THE STANDARDIZATION OF QUARTZ-CRYSTAL UNITS FOR MILITARY EQUIPMENT

CAPTAIN CHARLES J. MILLER, JR.
(Squier Signal Laboratory, Fort Monmouth, Red Bank, N. J.)

Some of the technical problems which must be solved before a series of ultimate standard quartz-crystal units for use in military signal equipment can be established are discussed, and progress to date in the solution of these problems is indicated. The crystal impedance meter, a new instrument for measuring the impedance of a crystal unit, is introduced and described. A brief review of the fundamental electrical properties of crystal units and associated oscillator circuits is included to furnish a technical background upon which to discuss these problems. A review of the three principal applications of crystal units in frequency-control circuits, calibrator circuits, and filter circuits, and a review of the various types of crystal holders and methods of mounting are included.

GLASS PROBLEMS IN THE MANUFACTURE OF MINIATURE TUBES

HENRY J. MILLER
(RCA Victor Division, Harrison, N. J.)

The use of miniature tubes in military equipment made it necessary to develop stem making and stem-to-bulb sealing techniques to provide tubes which would withstand without glass failure severe mechanical and thermal loading and shock as well as vibration. The three factors which govern the mechanical stability of the stem are buffer gas, depth of insertion, and strain. Methods of controlling these factors are described. The stem-to-bulb sealing technique required to obtain a seal of maximum mechanical rigidity is outlined. It is shown that the resulting procedures for the mass production of tubes were successful in withstanding the severe mechanical stress of wartime use without any epidemic glass failure in the field.

NOISE SPECTRUM OF CRYSTAL MIXERS

P. H. MILLER
(University of Pennsylvania, Philadelphia, Pa.)

Studies of the noise spectrum of crystal mixers were made over the frequency range of 50 to 1,000,000 cycles per second. In the audio range a band-pass filter employing a three-terminal Wien bridge was used to perform the analysis. For analysis at higher frequencies 7 megacycles were added to the noise spectrum and a communications receiver employed. It was found that regardless of the type of power applied to the crystal the noise temperature varies inversely with the frequency. The noise in the audio range is always large, a noise temperature ratio of 10^6 being typical. A mechanism responsible for the observed noise has not yet been suggested.

A NEW SYSTEM OF RADIO TELEMETERING

DAVID W. MOORE, JR., AND FRANK G. WILLEY
(Fairchild Camera and Instrument Corporation, Jamaica, L. I., N. Y.)

The Fairchild system of radio telemetering was designed to transmit indication of aircraft instruments from plane to ground over a conventional aircraft radio transmitting and receiving equipment. Ground indication is made by an indicator which closely simulates the standard aircraft instrument in appearance and modification to the aircraft instrument in the plane in flight. Instrument indication is transferred into electrical phase angle which may be transmitted by radio equipment. This phase angle is then compared with a reference signal in the receiving station and converted to a dial indication. Provision may be made for sending a number of instrument indications over a single carrier,

enabling transmission of indications of a flight group of instruments from, for example, a radio-controlled plane or missile to a distant operating point, either on the ground or in another plane.

MICROWAVE POWER MEASUREMENT

T. Moreno and O. C. Lundstrum
(Sperry Gyroscope Company, Inc., Garden City, L. I., N. Y.)

Possible methods of microwave power measurement are reviewed. The design requirements for bolometric wattmeters are outlined, and examples are given of bolometer elements that have been developed to meet these requirements. A recently developed bolometer element that may be used over an exceedingly wide band of frequencies is included. The results of experiments to determine the accuracy of these wattmeters are summarized; these experiments indicate that errors may be held to within a few per cent.

DIRECTIONAL COUPLERS

W. W. Mumford
(Bell Telephone Laboratories, New York, N. Y.)

The directional coupler is a device which samples separately the direct and the reflected waves in a transmission line. A simple theory of its operation is derived. Design data and operating characteristics for a typical unit are presented. Several applications which utilize the directional coupler are discussed.

AIRCRAFT AUTOMATIC POSITION PLOTTER

A. C. Omberg and W. L. Webb
(Bendix Radio Division, Baltimore, Md.)

The development of a device for feeding information from two automatic direction finders and a magnetic heading device into a computer, which changes polar co-ordinates into rectangular co-ordinates, is described.

The rectangular co-ordinates give the position of an aircraft with respect to two ground transmitters automatically controlling a "crab" which continuously plots the position of the aircraft on a chart. The method of developing the computer and a model of the device is described.

RADAR MODEL XAF

R. M. Page
(Naval Research Laboratory, Washington, D. C.)

This paper gives the story of the technical development of the U. S. Navy's first operational radar equipment, the XAF. Theoretical considerations and design parameters are given for pulse-modulation transmission and reception equipment, and exemplified in the XAF circuits. Of particular interest are the six-tube, high-frequency oscillator and the coupling circuits permitting efficient operation of both transmitter and receiver on the same antenna.

A NEW HIGH-SPEED RECORDING POTENTIOMETER

V. L. Parsegian
(Portable Products Corporation, C. J. Tagliabue Division, Brooklyn, N. Y.)

A new high-speed recording potentiometer is described, having a carriage travel of 10 inches in one second and balancing to within an accuracy of 0.1 per cent of full range. The instrument is of the photoelectric type, using a new sturdy, short-period, low-inertia-error galvanometer, a photocell, and a phase-reversing amplifier which drives a split-phase carriage motor when the photocell illumination exceeds, or is less than, an intermediate "balance" value. Means for canceling the galvanometer lag is described, as well as a new thyratron circuit for printing records.

AN INTRODUCTION TO HYPERBOLIC NAVIGATION

J. A. Pierce
(Radiation Laboratory, Massachusetts Institute of Technology, Cambridge, Mass.)

In less than five years, loran, the American embodiment of the new method of navigation, has grown from a concept into a service used by tens of thousand of navigators over three tenths of the surface of the earth. The first part of the present paper describes the history of this program. A second section deals with the fundamental concepts of hyperbolic navigation and gives some details regarding the kinds of equipment now employed for transmission, reception, and interpretation of pulse signals for this service.

JOINT ELECTRON TUBE ENGINEERING COUNCIL

O. W. Pike
(Joint Electron Tube Engineering Council)

This paper outlines the conditions leading up to the formation of the Joint Electron Tube Engineering Council as the joint body responsible for the technical aspects of tube standardization in the National Electrical Manufacturers Association and the Radio Manufacturers Association. The basic organization of JETEC is described, and its relation to the parent organizations and other agencies such as the Joint Army-Navy Committees is outlined. The activities of JETEC during the past year are summarized and its program for the future indicated.

MAGNETRON CATHODES

M. A. POMERANTZ
(Bartol Research Foundation of the Franklin Institute, Swarthmore, Pa.)

This paper will include a description of the spectacular high-pulsed emissions from oxide cathodes which were initially responsible for the success of magnetrons. Other matters which will be touched upon are decay of emission with time, cathode and anode sparking, the role of back-bombardment and secondary emission, and thoria cathodes.

ELECTRONIC FREQUENCY STABILIZATION OF MICROWAVE OSCILLATORS

R. V. POUND
(Radiation Laboratory, Massachusetts Institute of Technology, Cambridge, Mass.)

For many purposes, microwave signal generators of very-high-frequency stability are desirable. Two methods of electronic frequency control relative to the resonant frequency of an isolated microwave cavity resonator are discussed. The relative frequency can be maintained to better than one part in 10^8 and the absolute frequency stability is that of the cavity. High-fidelity frequency modulation with deviations of the order of $f/14Q$ about the stabilized frequency is possible. Several uses are mentioned.

FROM WIRING TO PLUMBING

E. M. PURCELL
(Radiation Laboratory, Massachusetts Institute of Technology, Cambridge, Mass.)

At microwave frequencies circuit components are needed which, although comparable to a wavelength in size, provide the functional flexibility of ordinary radio-frequency circuit elements. Connectors, rotating joints, T-junctions, transformers, filters, variable reactors, attenuators, etc., must be manufacturable, durable, and in electrical behavior accurately predictable. In some respects microwave circuits are simpler than their low-frequency counterparts. Line-length transformations are conveniently and freely employed. Also, the symmetry properties of wave-guide transmission modes permit the realization, in simple form, of networks with interesting and useful properties. With a few notable exceptions microwave circuit design has been reduced to an engineering science.

TELEVISION-STUDIO EQUIPMENT

JAMES J. REEVES
(Columbia Broadcasting System, New York, N. Y.)

The design of camera and studio control-room equipment, recently built and used by the Columbia Broadcasting System for the transmission of high-definition color television and 1029-line black-and-white images is described in detail.

MICROWAVE PROPAGATION

Part I

The Effect of Rain Upon the Propagation of Waves in the One- and Three-Centimeter Region

S. D. ROBERTSON AND A. P. KING
(Bell Telephone Laboratories, Inc., New York, N. Y.)

The effects of rainfall and atmospheric absorption on the propagation of microwaves and the methods employed for measuring them are described. The attenuation of 3.2-centimeter waves is slight for moderate and light rainfall. During a cloudburst, the attenuation may approach a value of 5 decibels per mile. At 1.09 centimeters, the waves are appreciably attenuated even by a moderate rain.

Part II

Propagation of Six-Millimeter Waves

G. E. MUELLER
(Bell Telephone Laboratories, Inc., New York, N. Y.)

Attenuations in excess of 25 decibels per mile have been observed during a cloudburst. The losses are still higher at 0.62 centimeter reaching a value of 42 decibels per mile for a cloudburst. The gas attenuation at this wavelength is probably less than 0.2 decibel per mile.

THE IMAGE ORTHICON, A SENSITIVE TELEVISION PICKUP TUBE

ALBERT ROSE, P. K. WEIMER, AND H. B. LAW
(RCA Laboratories, Princeton, N. J.)

The image orthicon is a new television pickup tube of high sensitivity. It operates stably at all light levels and the picture transmitted is substantially independent of the illumination over a wide range. Scenes have been transmitted successfully with one hundredth of the illumination previously required by commercial pickup tubes.

The advantageous features of the image orthicon have been attained by incorporating with the orthicon an electron multiplier, an electron-image section and a two-sided target. This new development is described in detail.

DUPLEX OPERATION OF INDEPENDENT HIGH-POWER OSCILLATORS FOR INDUCTION HEATING

W. C. RUDD
(Induction Heating Corporation, New York, N. Y.)

In the production of high-frequency power for induction heating, it has been found advantageous to use

multiple oscillators for the production of powers beyond that of a single unit. The problem involves the interconnection of two independent tank circuits in a manner such that the output frequency of the two units is the same and in synchronism. In addition, the total loan must be shared equally by the two power supplies. The paper describes the electrical problems involved, together with their practical solution for the production of powers of 40 and 50 kilowatts, using two 20- or two 25-kilowatt oscillators.

DESIGN CONSIDERATIONS IN BROADSIDE ARRAYS

JOHN RUZE
(Evans Signal Laboratory, Belmar, N. J.)

The various factors considered in the design of broadside arrays are discussed and their effect on antenna bandwidth as determined by pattern deterioration are mentioned. Mutual impedance between antenna elements and means of establishing a desired current and phase distribution are detailed. Various methods of lobing a broadside array with magnitude of secondary lobes and bandwidth are discussed. Several designs will be detailed, such as the antenna system used on the SCR-270 and the AN/CPX-1.

A FREQUENCY-MODULATION ALTIMETER FOR METER AND LIGHT INDICATION AND THE AUTOMATIC ALTITUDE CONTROL OF AIRCRAFT

R. C. SANDERS, JR., AND W. R. MERCER
(Raytheon Manufacturing Company, Watham, Mass.)
AND
IRVING WOLFF AND J. C. SMITH
(RCA Laboratories, Princeton, N. J.)

AN AUTOMATIC VISUAL-INDICATING RADIO DIRECTION FINDER

ALDO SCANDURRA AND SAMUEL STIBER
(Signal Corps Engineering Laboratory, Belmar, N. J.)

Radio set AN/TRD-2 is a Signal Corps development designed to provide a portable and mobile direction finder giving instantaneous indications and automatic sense. This direction finder is unique in that the instantaneous indication on the oscilloscope is a single ine generated from the center of the screen with a length proportional to the signal strength and the angular position of which indicates the direction of arrival of the signal without sense ambiguity. An additional feature is that noise and modulation are almost completely eliminated from the visual indication.

ELECTROOPTICAL CHARACTERISTICS OF TELEVISION SYSTEMS

O. H. SCHADE
(RCA Victor Division, Harrison, N. J.)

Optical and psychological capabilities of the human eye determine the performance standards for television systems.

Significant values for image detail and contrast, the electrical channel width, and signal-to-noise ratios are derived from the threshold visibility of picture detail and random brightness fluctuations.

Optical requirements and processes of developing electrical signals in television cameras for monochrome or color transmission are examined to establish relations and comparative values for obtainable signal-to-noise ratios and the required light flux.

SIGHT AND SOUND ON ONE CARRIER

KURT SCHLESINGER
(Columbia Broadcasting System, New York, N. Y.)

The fundamental aspects of audio and video multiplex operation are outlined, and a description of the various forms of multiplex modulation is given. Theoretical and experimental considerations of performance characteristics are considered. There is a detailed discussion of transmitter and receiver circuits and a discussion of results of recent tests.

EQUIVALENT CIRCUITS FOR WAVE-GUIDE STRUCTURES

JULIAN SCHWINGER
(Radiation Laboratory, Massachusetts Institute of Technology, Cambridge, Mass.)

Wave-guide structures can be completely and rigorously described by equivalent lumped-constant circuits. It is the purpose of the lecture to show how typical equivalent circuits are constructed by employing the special symmetry of the situation, to demonstrate that much qualitative information can be obtained from the form of the circuit even without knowledge of the values of the circuit constants, to discuss how the values of the circuit constants can be directly measured, and to indicate the procedure of the theory in calculating the values of the circuit parameters in their complete dependance on frequency and geometry.

DISCRIMINATORS FOR FREQUENCY-MODULATION RECEIVERS

S. W. SEELEY
(RCA Laboratories, New York, N. Y.)

Many of the aspects of frequency-modulation detection, including the new amplitude insensitive discriminators, are discussed.

ULTRA-HIGH-FREQUENCY TELEVISION TRANSMITTERS AND ANTENNAS

ROBERT SERRELL
(Columbia Broadcasting System, New York, N. Y.)

Ultra-high-frequency television transmitters of several types have been developed and built in the Columbia Broadcasting System laboratories. These transmitters embodying tubes developed during the war, utilize a 10-megacycle modulation bandwidth. The design and performance of these transmitters and of wide-band antennas used will be described in detail. Also, some results of experimental ultra-high-frequency broadcasts are discussed.

MEASUREMENT OF THE ANGLE OF ARRIVAL OF MICROWAVES

W. M. SHARPLESS
(Bell Telephone Laboratories, Inc., New York, N. Y.)

This paper describes a method of measuring the direction from which microwaves arrive at a given receiving site. Data which have been collected on two short optical paths using a wavelength of $3\frac{1}{4}$ centimeters are presented to illustrate the use of the method. Angles of arrival as large as $\frac{1}{2}$ degree above the true angle of elevation have been observed in the vertical plane while no variations greater than $\pm 1/10$ degree have been found in the horizontal plane. More recent work, using a lens-type scanning antenna operated at a wavelength of $1\frac{1}{4}$ centimeters revealed that, at times, as many as four distinct transmission paths were present simultaneously on a 12.6-mile circuit. Simultaneous meteorological soundings were made near both terminals of the circuit.

MODEL AIRCRAFT-ANTENNA MEASUREMENTS

GEORGE SINCLAIR, E. W. VAUGHAN, AND EDWARD C. JORDAN
(Ohio State University Foundation, Columbus, Ohio)

Although antenna models have been used for many years in studying antenna patterns, the measurements were severely limited as to frequency and type of antenna. It is shown how the techniques may be extended to cover a very wide frequency range and a wide variety of antennas. Particular application to the study of aircraft antenna patterns are cited. The utility of models in studying special properties of antennas, such as polarization errors of direction finders, propeller-modulation effects, ellipticity of polarization, etc., are discussed.

ONE-MILLIONTH-OF-A-SECOND RADIOGRAPHY AND ITS APPLICATIONS

C. M. SLACK AND D. C. DICKSON
(Westinghouse Electric Corporation, Bloomfield, N. J.)

The making of ultra-speed radiographs, using exposure times of the order of one millionth of a second, requires the passage of electron currents of 1000–2000 amperes. Such currents can be supplied by an electron source utilizing field emission from a cold-cathode electrode which degenerates into a metallic arc in a high vacuum. The recording of such high-speed transients are briefly discussed. The development of this equipment has been greatly accelerated because of the war. Slides showing its applications to various radiographic problems requiring short exposure times which have just been released by the War Department are shown; among these are radiographs taken at Frankford Arsenal and Aberdeen Proving Grounds of exploding shells and bombs, and at Princeton University, showing the wounding mechanism of high-velocity fragments. Future applications also are discussed.

THEORY OF IMPULSE NOISE IN IDEAL FREQUENCY-MODULATION RECEIVERS

DAVID B. SMITH AND W. E. BRADLEY
(Philco Corporation, Philadelphia, Pa.)

An analytical treatment of noise in frequency-modulation receivers is given for the case when a mixture of noise and useful signals is applied to the receiver input. Methods of measuring the performance of receivers with respect to frequency-modulation noise are discussed.

GROUND-CONTROLLED APPROACH

ERNEST STORRS, W. DEVITT, AND BEN GREEN
(Watson Laboratories, Red Bank, N. J.)

Out of the development race for military supremacy in World War II has come one of the most outstanding navigational aids yet known. It is known as ground-controlled approach or, more popularly termed, GCA. The military designation has been the nomenclature AN/MPN-1. Its purpose is to talk the pilot down the glide path under conditions approaching zero visibility to a safe landing by means of the normal communications equipment already installed in the aircraft.

A KINESCOPE FOR HOME PROJECTION-TYPE TELEVISION RECEIVERS

L. E. SWEDLUND
(RCA Victor Division, Harrison, N. J.)

The development of a small high-voltage cathode-ray tube for home projection-type television receivers,

soon to be available commercially, is described. Several new insulation and fluorescent screen problems had to be solved because of the need for operating at relatively high voltage. An outstanding gain in light output and performance was attained by applying an electron-transparent, light-reflecting aluminum film to the back of the fluorescent screen.

HIGH-FREQUENCY PLATED QUARTZ-CRYSTAL UNITS FOR CONTROL OF COMMUNICATIONS EQUIPMENT

R. A. Sykes
(Bell Telephone Laboratories, Inc., New York, N. Y.)

A description is given of the general problems relating to the development of high-frequency plated-crystal units, the methods employed for supporting the crystal blank, adjustment to final frequency by means of vaporized or evaporated films, and the various problems associated with the aging of such units. The general problems of devising simplified procedures for the large-scale manufacture of such crystal units are also described.

CRYSTAL RECTIFIERS IN HETERODYNE RECEIVERS

H. C. Torrey
(Radiation Laboratory, Massachusetts Institute of Technology, Cambridge, Mass.)

Crystal rectifiers as frequency converters are superior to other detectors of microwave signals as measured by the noise figure—a quantity dependent on conversion loss and noise temperature of the mixer. Linear-network theory can be applied to microwave converters, a mixer being represented as a three-terminal pair device with terminals at signal, image sideband, and intermediate frequency. Such a representation is helpful in estimating the effect on conversion loss of image-sideband termination and of parasitic impedances. Other factors of importance are resistance to burnout and stability. Representative microwave mixers designed by Radiation Laboratory are described.

RADAR ASPECTS OF NAVAL FIRE CONTROL

Captain Dundas P. Tucker
(U. S. Navy, Bureau of Ordnance, Navy Department, Washington, D. C.)

Application of radar to fire control required the development of many new designs and techniques for the purpose of providing high precision in measuring target position and high resolution against multiple targets and interfering objects. A special circuit for measuring time intervals to 0.05 microsecond, and angles to 0.05 degree were developed. American possession of radar-controlled gunfire was a decisive factor in many naval engagements with Japanese ships and aircraft.

BEAM-SHAPING METHODS IN ANTENNA DESIGN

L. C. Van Atta
(Radiation Laboratory, Massachusetts Institute of Technology, Cambridge, Mass.)

The angular width of an optical searchlight beam is determined by the extended light source placed at the focal point of the paraboloid reflector and by inaccuracies in the reflector shape. The beam width of a microwave paraboloid antenna, however, is due to diffraction of the radiation at the aperture. For sharp beams, it is desirable, frequently, to distribute the radiation in some manner other than that determined by diffraction. The focusing property of the antenna system can be modified either by providing an extended antenna feed or distorting the paraboloid shape. Straightforward experimental and theoretical approaches are available to the antenna designer in achieving a wide variety of beam shapes for special application.

STAGGER-TUNED WIDE-BAND AMPLIFIERS

H. Wallman
(Radiation Laboratory, Massachusetts Institute of Technology, Cambridge, Mass.)

In radar and television receivers, the simplicity of single-tuned circuits strongly commends itself to the designer of wide-band, band-pass amplifiers. Unfortunately, with present tubes, one cannot make a high-gain amplifier wider than about 4 megacycles; the principal reason is the rapidity with which bandwidth decreases as identical single-tuned stages are cascaded. This paper describes the scheme of stagger-tuning the individual single-tuned circuits, which essentially eliminates the shrinking of over-all bandwidth and thus makes possible very simple 10- and 15-megacycle wide amplifiers. Stagger-tuning appears to be much less well known than it deserves. Graphs are presented condensing the whole basic design of a wideband amplifier into the work of a few minutes; actual examples of amplifiers are shown.

METALLIZED-GLASS ATTENUATORS FOR RADIO-FREQUENCY APPLICATIONS

Ernst Weber
(Polytechnic Institute of Brooklyn, Brooklyn, N. Y.)

Based on special techniques of precision metallizing of glass plates and tubes, power-absorbing elements have been developed suitable for use in calibrated attenuators in coaxial as well as wave-guide radio-

frequency power transmission systems of moderate power level. Particular attention had to be given to proper matching of the attenuating sections to the practically lossless transmission lines by means of impedance transformers which themselves are part of the metallized-glass elements. Several models with precision measuring drives were developed for use as reference standards.

THE NEW "SPEEDOMAX" POWER-LEVEL RECORDER

A. J. Williams, Jr., and W. R. Clark
(Leeds and Northrup Company, Philadelphia, Pa.)

The new "Speedomax" power-level recorder is an instrument that faithfully records rapid or slow variations in power level with time, and is independent of variations in frequency within its frequency range (25 to 150,000 cycles). The recorder scale is linear in decibels. A 20-decibel change in power input can be recorded in about one second. The new circuits used in this new recorder are described in detail, and its performance characteristics are given.

A PULSE ALTIMETER OF HIGH ACCURACY AT HIGH ALTITUDES

Irving Wolff, W. D. Hershberger, G. W. Leck and R. R. Welsh
(RCA Laboratories, Princeton, N. J.)

COLOR-TELEVISION TRANSMITTER

N. H. Young
(Federal Telecommunication Laboratories, Inc., New York, N. Y.)

On December 21, 1945, Federal Telecommunication Laboratories delivered to the Columbia Broadcasting System a color-television transmitter. It operates on a carrier frequency of 490 megacycles with a peak power output of 1 kilowatt and can be modulated uniformly at all frequencies from direct current to 10 megacycles. It is the most powerful transmitter of this frequency and bandwidth ever used in television service.

The transmitter is made possible by the development of a new ultra-high-frequency triode, type 6C22. This tube is used in the four final stages of the radio-frequency section and in the two final stages of the video-frequency section.

A conventional sequence of crystal oscillators and frequency multipliers is used in the radio-frequency section. The video-frequency section is unusual chiefly in the use of direct-current coupling between amplifier stages, thus making the use of direct-current restoring circuits unnecessary. The final radio-frequency amplifier is grid-modulated, and the low plate resistance of the tube aids greatly in securing adequate bandwidth in the output radio-frequency circuit.

HERMETICALLY SEALED METAL HOLDER FOR CRYSTAL UNITS

A. W. Zeigler
(Bell Telephone Laboratories, Murray Hill, N. J.)

A metal-type holder has been developed to replace the phenolic-type for hermetically sealing low- and high-frequency crystal units for use by the various branches of the Armed Forces. The holder comprises an assembly of a drawn-metal cover fluxless soldered by induction heating to a base carrying glass-to-base seal terminals. The techniques developed follow closely those used in miniature vacuum-tube assemblies. Similar holders are being developed for peacetime applications in the communication field.

Awards

W. C. White, chairman of the Awards Committee, presented to the Board of Directors on November 7, 1945, the list of nominees selected for the 1946 Awards. These recommendations were unanimously approved by theBoard, and the Awards were presented at the Banquet of the Winter Technical Meeting held on Thursday, January 24, 1946.

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Medal of Honor—1946

RALPH VINTON LYON HARTLEY

"For his early work on oscillating circuits employing triode tubes and likewise for his early recognition and clear exposition of the fundamental relationships between the total amount of information which may be transmitted over a transmission system of limited bandwidth and the time required."

❖

Fellow Award—1945

THOMAS LYDWELL ECKERSLEY

"For his outstanding contributions to the theory and practice of radio-wave-propagation research. Both his approach to the problem from the standpoint of practical communications and his invention of mathematical tools useful in the computation of radiated fields are achievements of lasting value acclaimed by the whole radio world, and form a monument of which he may be justly proud."

❖

Fellow Award—1945

CLARENCE W. HANSELL

"For his pioneer work in the development and application of equipment for the ever higher frequencies employed for radio communication."

Fellow Award—1945

GREGORY BREIT

"For pioneering in the experimental probing of the ionosphere and giving to the world the first publication of the experimental proof of the existence of the ionosphere; and for having initiated at an early date the pulse method of probing by reflection which is the basis of modern radar."

❖

Fellow Award—1945

HENRI G. BUSIGNIES

"For his accomplishments in the field of radio direction finders, particularly pioneering work on instruments having automatic indicating features."

Morris Liebmann Memorial Prize—1945

PETER C. GOLDMARK

"For his contributions to the development of television systems, particularly in the field of color."

❖

Fellow Award—1945

HAROLD LESTER KIRKE

"For his services to broadcasting in the British Isles and in particular for his leadership in the research activities of the British Broadcasting Corporation."

❖

Fellow Award—1945

JOSEPH SLEPIAN

"In recognition of his contributions as scientist, engineer, and inventor to the field of electronics."

❖

Conway Studios, Inc.

Fellow Award—1945

HAROLD S. OSBORNE

"For his contributions in the electrical communication field including outstanding leadership and direction in the application of new techniques to telephony."

Fellow Award—1945

HOWARD A. CHINN

"For his contributions to improved broadcasting."

❖

Fellow Award—1945

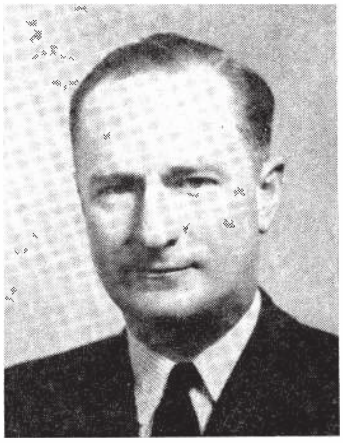
JULIUS A. STRATTON

❖

Fellow Award—1945

ARTHUR L. SAMUEL

"For his fundamental work in the field of electronic research and for development of electronic devices of particular value at very high frequencies."



Fellow Award—1945

WALTER C. EVANS

"In recognition of his past contributions to radio and his present active participation in the affairs of the Institute."

❖

JULIUS A. STRATTON

"In recognition of his contributions as a teacher and author, adapt in the field of fundamental research who has applied his knowledge to improve radio communications."

❖

MERLE ANTHONY TUVE

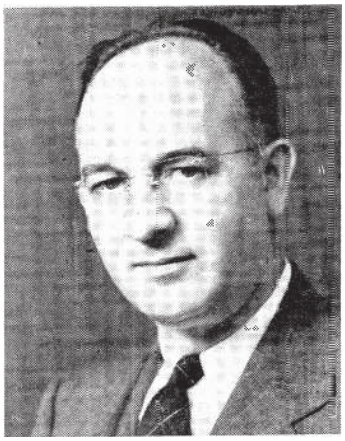
"For pioneering in the experimental probing of the ionosphere and giving to the world the first publication of the experimental proof of the existence of the ionosphere; and for having initiated at an early date the pulse method of probing by reflection which is the basis of modern radar."

❖

Fellow Award—1945

WILLIAM O. SWINYARD

"In recognition of his work in promoting electronics and the affairs of the Institute, particularly in his district."



Fellow Award—1945

ELMER D. MCARTHUR

"For his developments in the field of ultra-high-frequency electron tubes."

❖

Fellow Award—1945

MERLE ANTHONY TUVE

❖

K. Rarich

Fellow Award—1945

RONALD J. ROCKWELL

"For active work in the affairs of the Institute and in the engineering of high-power international broadcast transmitters."

Institute News and Radio Notes

Board of Directors

December 5 Meeting: At the regular meeting of the Board of Directors, which was held on December 5, 1945, the following were present: W. L. Everitt, president; G. W. Bailey, executive secretary; S. L. Bailey, W. L. Barrow, L. M. Clement, W. H. Crew, assistant secretary; R. F. Guy R. A. Hackbusch, R. A. Heising, treasurer; Keith Henney, F. B. Llewellyn, B. E. Shackelford, D. B. Sinclair, H. M. Turner, H. A. Wheeler, and W. C. White.

Executive Committee Actions: It was unanimously approved that the actions of the Executive Committee taken at its November 7, 1945, meeting, be ratified.

Committees

Building-Fund: Dr. Shackelford, chairman of the I.R.E. Building-Fund Committee, reported that the Fund had passed $623,000, and that the final report of the Building-Fund Committee would be submitted at the January meeting.

Tellers: The report of the Tellers Committee, dated November 15, 1945, was unanimously approved.

Constitution and Bylaws

Executive Committee: It was unanimously approved to adopt, as of December 3, 1945, the following amended Bylaw, Sec. 27:

"Sec. 27—The Executive Committee shall be responsible for the management of the office of the Institute, which shall include special activities, technical activities, office operations, accounting, advertising, and publications, and the setting of salaries (with the exception of Officers' salaries) in all instances in the limits of the budget. Such activities as the Executive Committee shall direct shall be administered by Executive Secretary. The salary of the Executive Secretary shall be determined by the Executive Committee."

Price of PROCEEDINGS *in Annual Dues:* It was unanimously approved to adopt, as of December 3, 1945, the following amended Bylaw Sec. 57:

"Sec. 57—The price of a single annual subscription to the PROCEEDINGS for a Fellow, Senior Member, Member, or Associate shall be $6.00, to be included in his annual dues as specified in Article IV of the Constitution."

Regional Representation Plan: The Board considered the proposed Constitutional Amendments for the Regional Representation Plan and made suggestions for minor changes which will be made in the final draft by the Constitution and Laws Committee. The following actions were taken:

a. The term "Regional Committee" was adopted.

b. The entire group of proposed Constitutional Amendments for Regional Representation will be submitted to the membership as the only option, and modifications in the Constitution which are desirable, but not essential, to the Plan may also be included in the group.

Student Status: It was unanimously approved that the Board rescind the previous motion of October 3, 1945, approving two and one-half years in Student status.

Postponement of Dues: It was unanimously approved that the Board approve the recommendation of the Executive Committee that the final date of payment of 1946 dues outside of United States and Canada be extended from April 30 to June 30, 1946.

Appointment: Dr. Alfred N. Goldsmith was reappointed as I.R.E. representative on the Standards Council, and Mr. Raymond F. Guy as alternate, for the three-year period, 1946–1948.

Executive Committee

December 5 Meeting: The Executive Committee meeting, held on December 5, 1945, was attended by W. L. Everitt, president; G. W. Bailey, executive secretary; S. L. Bailey, W. L. Barrow, E. F. Carter, W. H. Crew, assistant secretary; R. A. Heising, treasurer; and F. B. Llewellyn (guest).

Membership: Approval was given to the 390 applications for membership in the Institute listed on page 46 A of the January, 1946, issue of the PROCEEDINGS of the I.R.E. and WAVES and ELECTRONS. These applications are as follows:

For Transfer to Senior Member grade	15
For Admission to Senior Member grade	7
For Transfer to Member grade	52
For Admission to Member grade	53
For Admission to Associate grade	169
For Admission to Student grade	94
Total	390

Committees

The following appointments were approved:

EDUCATION

R. W. Jones, Glenn Koehler, Jack D. Ryder, Elmer H. Schulz, Robert P. Siskind, Karl Spangenberg, Alexander H. Wing, Jr.

FACSIMILE

E. F. Watson

PIEZOELECTRIC CRYSTALS

Paul L. Smith

TELEVISION

W. F. Bailey, S. Maulner, M. E. Strieby

RADIO RECEIVERS

J. M. Pettit

RADIO WAVE PROPAGATION

Earl Cullum

URSI: It was unanimously approved that the Institute of Radio Engineers cooperate with the International Radio and Scientific Union in the Spring Meeting.

Sixth Annual Broadcast Engineering Conference

Under the joint sponsorship of The Ohio State University and the University of Illinois and with the continued co-operation of the National Association of Broadcasters and The Institute of Radio Engineers, the Broadcast Engineering Conference will be resumed this year. This is a continuation of the annual conferences held during the years from 1938–1942, inclusive. Dr. W. L. Everitt, now head of the department of electrical engineering at the University of Illinois, Urbana, Illinois, will continue to act as the director with Professor E. M. Boone of The Ohio State University as associate director.

The 1946 conference will beheld at The Ohio State University in Columbus, Ohio, during the week of March 18–23. The conference will be held annually, and the place of meeting will alternate between the campus of The Ohio State University and that of the University of Illinois. Emphasis in the program will be placed on the impact of developments since 1942 on operating problems in broadcast engineering, including frequency modulation and television.

As a result of the war, many engineers have moved or changed their affiliations, and many new men have entered the field. The mailing list accumulated during previous conferences is obviously out of date. The director requests that those interested notify him of their present address so that they can be informed of the details of the program as soon as available. Communications to Dr. Everitt should be addressed c/o University of Illinois, Urbana, Illinois.

PROGRAM

All meetings to be held in Campbell Hall Auditorium, The Ohio State University

Monday, March 18

9:00 A.M. to 1:00 P.M.

"Contributions of War Developments to Broadcasting" by A. B. Chamberlain, Chief Engineer, Columbia Broadcasting System

"Symposium on Broadcast Maintenance Problems," by A. J. Ebel, Chief Engineer, University of Illinois Radio Service, *Chairman*

2:30 P.M. to 4:30 P.M.

"Design of Broadcast Studios with Irregular Boundary Surfaces," by K. C. Morrical and J. E. Volkman, Radio Corporation of America

Tuesday, March 19

9:00 A.M. to 1:00 P.M.

"Antenna Patterns and the Antennalyzer," by George H. Brown, Research Engineer, Radio Corporation of America

"Symposium on Recording Techniques," by Lynn Smeby, Associate Director, Operational Research Staff, Office of the Chief Signal Officer, U. S. War Department

2:30 P.M. to 4:30 P.M.

General Acoustical Problems in Broadcasting," by E. J. Content, Station WOR

Wednesday, March 20

9:00 A.M. to 1:00 P.M.

"Symposium on Very-High-Frequency Antenna and Coupling Circuits," by E. C. Jordan, Department of Electrical Engineering, University of Illinois, *Chairman*

"Symposium on Television-Station Operation," by Robert E. Shelby, National Broadcasting Company, *Chairman*

2:30 P.M. to 4:30 P.M.

"Radio Relays for Frequency Modulation and Television"

Thursday, March 21

9:00 A.M. to 1:00 P.M.

"Stratovision," by Ralph Harmon, Westinghouse Electric Corporation, and representatives from Glenn L. Martin Aircraft Co.

"Round Table and Question Box," by A. D. Ring, Consulting Engineer, *Chairman;* John Willoughby, Assistant Chief Engineer, Federal Communications Commission, in charge of Broadcasting; also representative chief engineers from broadcasting stations.

2:30 P.M. to 4:30 P M.

"Interconnecting Facilities for Frequency Modulation and Television Broadcasting," by H. I. Romnes and W. E. Bloecker, American Telephone and Telegraph Company

Friday, March 22

9:00 A.M. to 1:00 P.M.

"High-Powered Tubes for Very-High-Frequency Operation," by W. W. Salisbury, Collins Radio Company

"Symposium on Frequency-Modulation Operating Problems," by Philip B. Laeser, *Milwaukee Journal* Company, *Chairman*

2:30 P.M. to 4:30 P.M.

"Symposium on Frequency-Modulation Monitors," by R. C. Higgy, Director WOSU, Ohio State University, *Chairman;* D. B. Sinclair, General Radio Company; Frank Gunther, Radio Engineering Laboratories; H. R. Summerhayes, Jr., General Electric Company

Saturday, March 23

9:00 A.M. to 1:00 P.M.

"Symposium on Frequency-Modulation Methods," by W. L. Everitt, Head, Department of Electrical Engineering, University of Illinois, *Chairman*

"Symposium on Field Experiences in Very-High-Frequency Propagation," by Raymond M. Wilmotte, Consulting Engineer, *Chairman*

Tuesday, March 19

8:00 P.M.

Popular Scientific Lecture, University Hall, The Ohio State University

Thursday, March 21

6:30 P.M.

Banquet, Fort Hayes Hotel

Radio Pioneers' Dinner

The New York Section of the Institute of Radio Engineers held its fourth Radio Pioneers' Dinner at the Hotel Commodore in New York City on the evening of November 8, 1945. The General Committee, under the chairmanship of Louis Gerard Pacent, planned ambitiously and effectively; the attendance of over 800 eclipsed by far any other dinner meeting of the Section and has been exceeded only seldom at national convention banquets of the Institute.

The American Radio Relay League, Radio Club of America, and Veteran Wireless Operators Association were guests of the Section and were represented by their presidents: George Bailey, also executive secretary of the Institute; Fred Klingenschmitt; and William J. McGonigle, respectively. President Everitt of the Institute was master of ceremonies.

Although the keynote of the evening was fun, John V. L. Hogan, who together with Robert H. Marriott and Alfred N. Goldsmith was responsible for the merging of the Wireless Institute and the Society of Wireless Telegraph Engineers into the Institute, read excerpts of a brief address he prepared for the occasion. His theme, "radio will be developed faster if those engaged in it will work together more," was taken from a letter sent by Mr. Marriott in 1909 to some 200 wireless people who, it was hoped, would be interested in founding a radio society, the Wireless Institute.

Mr. Marriott, first president of both the Wireless Institute and the Institute of Radio Engineers, and Dr. Goldsmith, indefatigable worker and supporter of the Institute and editor of its publications, were unable to be present. Their messages, read by President Everitt, did much to soften the reality of their absence.

Held during the week commemorating the twenty-fifth anniversary of the initiation of radio broadcasting, it was fitting for The American Broadcasting Company to arrange for Deric Leighton to direct a skit depicting some of the early trials of "Wireless Pioneering," for Ed East to entertain at the piano, and for Ray Knight to tell of the "Early Days and Late Nights."

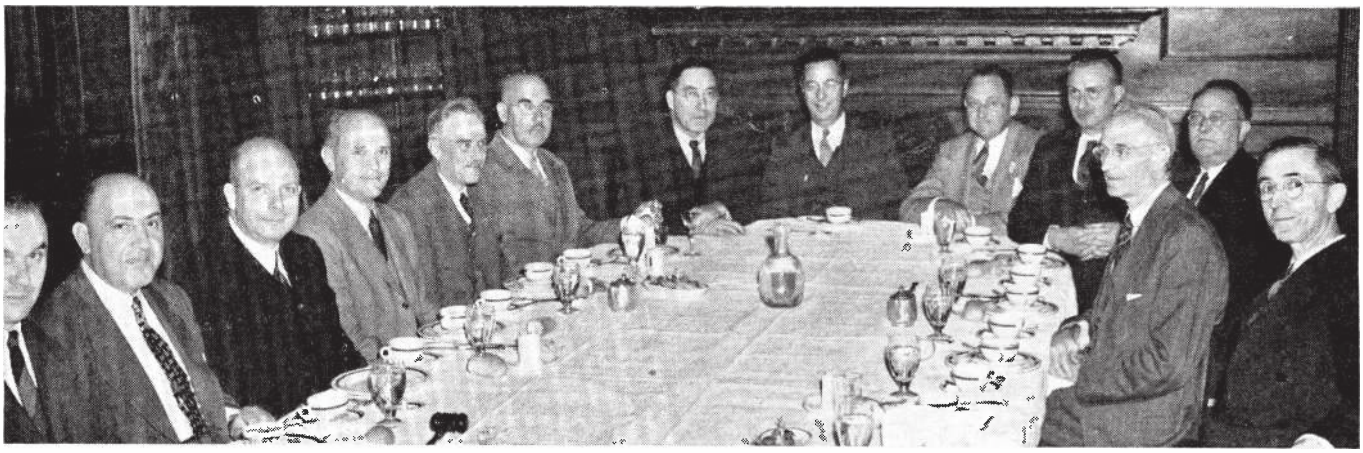
Some twenty gifts were contributed as door prizes. Included among them was an unannounced surprise which was won by General Van Deusen—a week-old bull calf—pointfree! As the prizes were drawn, they were augmented by others put up by those present. Among the "upsets" were the winning of a General Electric receiver by Louis Pacent, Jr., presented by the chairman of the Prize Committee, his boss, Dorman Israel, vice-president of Emerson, and the selection of E. M. Deloraine, vice-president-elect of the Institute and president of the International Telephone and Telegraph International Telecommunication Laboratories, as the recipient of a National communications receiver.

Sergeant Irving Strobing, who transmitted the last message from Bataan before it was overrun by the Japanese, was introduced and expressed his desire to continue his radio studies. Jack Poppele, chairman of the Scholarship Committee of the Veteran Wireless Operators Association, presented him with a scholarship in the Capital Radio Engineering Institute, an on-the-spot decision of the officers of that organization.

Reproduced on the editorial page of this issue, are messages from two of the honored guests who were present, Admiral Redman and General Ingles, heads of communications of the Navy and Army. The significance and scope of their tributes to all radio-and-electronic engineers for outstanding accomplishments in the war efforts, place their statements far beyond the confines of any "old-timers dinner."

Jack Binns, famed radio operator of the

Louis G. Pacent, general chairman of the Radio Pioneers' Dinner of the New York Section presenting the gavel of master of ceremonies to Dr. Everitt, president of the Institute.



The group responsible for the Radio Pioneers' Dinner is shown above. Around the table from left to right are George B. Hoadley, chairman of the New York Section; Louis G. Pacent, general chairman of the Dinner Committee; W. L. Everitt, president of the Institute and master of ceremonies; Roger M. Wise; Glen Payne; Raymond Guy; Ralph R. Batcher, secretary; Edward J. Content, treasurer; D. W. May; P. R. Morton; J. C. Stroebel; H. C. Gawler; and E. L. Bragdon. Missing were vice-chairman George Lewis, O. H. Caldwell, George H. Clark, George C. Connor, John Di Blasi, Hugo Gernsback, O. B. Hanson, J. Q. A. Holloway, Robert H. Marriott, Dorman D. Israel, Harry Sadenwater, and Harold P. Westman.

S.S. Republic disaster, tried his fist, not too successfully, on the first radio set offered for sale to the general public. Built by the Electro Importing Company in 1909, its spark-coil transmitter and coherer-and-electric-bell detector were too slow for Binns' still-modern fist. The presence of various representatives of the Federal Communications Commission was evidence of the wisdom of Hugo Gernsback in obtaining a special license for the operation of the transmitter at the dinner.

A souvenir booklet, unique perhaps in that it carried no advertising, was devoted to a seriously presented history of wireless from its early beginnings through 1925. Designed to stimulate the memories of all old-timers, it contained numerous pictures of equipment and personalities inextricably associated with the "good old days."

Miniature replicas of volume I, number 1, of *Modern Electrics*, published in April, 1908, were also distributed through the courtesy of Hugo Gernsback. This was the first regular magazine in America devoted to wireless.

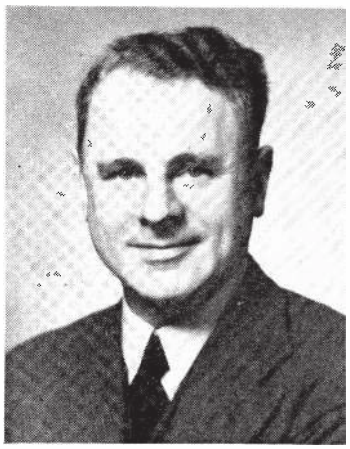
Twenty-seven commercial organizations made financial contributions to the success of the meeting. The General Committee planned so well that not only was the deficit from the cocktail party, dinner, and souvenir booklet covered, but the New York Section was enabled to make a substantial contribution to the Building Fund of the Institute.

I.R.E. People

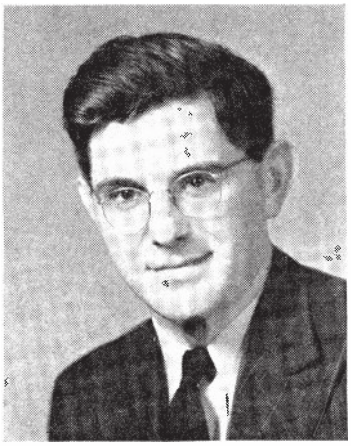
Canadian Short-Wave Broadcasting

A new short-wave international broadcast station has been established by the Canadian Broadcasting Corporation near Sackville, New Brunswick. The equipment includes two 50-kilowatt short-wave transmitters. Space is available for an additional 7.5-kilowatt short-wave transmitter.

Installation of the equipment was supervised by Joseph M. Conroy (A'23) and Fred R. Quance (A'42), engineers of the RCA Victor Division at Camden, New Jersey. The layout of the building housing the equipment was carried out by a group of engineers under the direction of G. W. Olive (A'29) of the same organization. Numerous technical problems of interest were encountered and solved in the design and installation of this new Canadian Station CHTA.



G. W. Olive

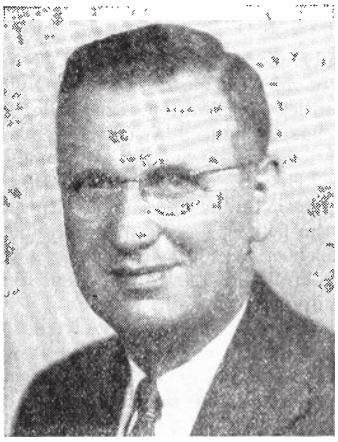


Fred R. Quance

Joseph M. Conroy

Harris and Ewing

RAYMOND M. WILMOTTE



PAUL H. CRAGO

G. CURTIS ENGEL

NEW WILMOTTE LABORATORY

Raymond M. Wilmotte (M'29-F'38), director of Wilmotte Laboratory, Inc., of Washington, D. C., recently announced the opening of a branch laboratory at 236 West 55 Street, New York 19, N. Y., offering engineering services in the application of electronics to industrial uses.

During the war, Wilmotte Laboratory devoted its activities largely to research and development for the Army, Navy, and Office of Scientific Research and Development. Much of this work was on radar, fire control, and other special devices. In the course of this work, the Wilmotte Manufacturing Company was organized to produce special electronic devices.

It is Mr. Wilmotte's intention to expand this combination of facilities in order to provide industrialists with complete engineering services applying the full potentialities of electronics to their processes.

The New York laboratory will be under the supervision of Paul H. Crago (A'44), who was section engineer with the Union Switch and Signal Company, in charge of design and application of electromagnetic signaling devices for railroads. He was more recently with Specialties, Inc., as executive engineer in charge of research and development of ordnance instruments for the Armed Forces, and the Federal Telephone and Radio Corporation.

G. Curtis Engel (A'45), formerly production manager of General Electronics, Inc., and manager of the laboratory of General Time Instruments Corporation, will head a group specializing in electronic controls and inspection methods. Another group will do consulting work in the application of dielectric heating.

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E. C. PAGE AND J. WESLEY KOCH

Lieutenant Colonel E. C. Page (M'42–SM'43), director of engineering of the Mutual Broadcasting System, has announced that Captain J. Wesley Koch (J'29–S'33–A'36–M'45) joined the engineering staff of the network on October 15 when he was released from the Army.

While in the Army, Captain Koch served as technical adviser of the Radio Propagation Unit and was concerned with radio propagation conditions throughout the world. He was a staff radio officer at Allied Force Headquarters in North Africa and Italy, and until October, 1945, he was with the office of the Chief Signal Officer at Baltimore, Maryland.

Captain Koch is a native of Nebraska and received his B.S. degree in electrical engineering at the University of Nebraska in 1934. It was while he was at the University that he designed and constructed special equipment for a wired-radio program distributing system operated by the Program Service of Lincoln, Nebraska. He later accepted a position with KFEQ, St. Louis, Mo., in 1934, as chief engineer. It was here that he designed and constructed most of the transmitting equipment at this station. After installing a complete new transmitting plant at KFEQ in 1942, Captain Koch resigned to accept a commission with the Signal Corps.

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JACK KAUFMAN

Jack Kaufman (A'30–SM'44) has been appointed a vice-president of the Aireon Manufacturing Corporation. He recently joined the organization to head the new San Francisco office which serves the transportation and communications industries on the Pacific Coast.

A graduate of the University of California in 1917, Mr. Kaufman has been engaged for a number of years in electronics in San Francisco. He was formerly president of Heintz and Kaufman, Limited, and executive vice-president of Globe Wireless, Ltd.

Mr. Kaufman formerly was president of the West Coast Electronic Manufacturers' Association, San Francisco Council, and vice-president of the coast-wide group of the same Association. Until recently, he was a member of the Industry Advisory Committee with the Board of War Communications.

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E. C. PAGE

J. WESLEY KOCH

Fabian Bachrach

HUGH S. KNOWLES

HUGH S. KNOWLES

Hugh S. Knowles (A'25–F'41), vice-president and chief engineer of the Jensen Radio Manufacturing Company, recently was elected president of the Acoustical Society of America.

Before graduating from Columbia University, Mr. Knowles was an editor of *Popular Radio;* technical columnist for the *New York Herald Tribune;* manager of Columbia University's experimental radio station; and president of the University's Radio Club. After receiving his Bachelor's degree, he undertook further work at Columbia and extensive graduate work at the University of Chicago. As a guest lecturer at Chicago University, he prepared and gave a graduate course on sound and vibrating systems. Mr. Knowles then served as radio engineer for Hammarlund Manufacturing Company and as manager of the parts division of Silver-Marshall. In 1931, he joined the staff of the Jensen Radio Manufacturing Company as chief engineer and was elected to the position of vice-president in charge of product research and development in 1940.

Mr. Knowles was chairman of the Committee on National Defense, the Electroacoustics Standards Committee of The Institute of Radio Engineers, and Sound Equipment Standards Committee of the Radio Manufacturers Association. He has also represented the IRE and the RMA on various electroacoustical committees of the American Standards Association, and he served as chairman of the Chicago Section of the IRE. Mr. Knowles received the Fellowship Award of the IRE for "engineering leadership in the field of acoustics and its radio applications."

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NORMAN B. NEELY

Norman B. Neely (A'39), West Coast manufacturers' representative for several electronic firms, has resumed active management of his firm, Norman B. Neely Enterprises of Hollywood, California. During the war, Mr. Neely was associated with Western Electric Company as special field engineer engaged in confidential work on Army Air Force equipment contracts.

PAUL D. ZOTTU

Paul D. Zottu (A'31–M'38–SM'43–F'44), formerly chief engineer, Thermex Division, the Girdler Corporation, Louisville, Kentucky, has announced his entrance into the field of consulting industrial electronic engineering. He offers to industrial users and equipment manufacturers a consulting service in the field of high-frequency induction and dielectric heating, specializing in applications, equipment and component design, and equipment selection.

Mr. Zottu has an extensive background in the radio field covering a wide range of activities. The last seven years, outside of the part time spent at the Radiation Laboratory at Massachusetts Institute of Technology, have been devoted entirely to industrial high-frequency heating problems. In this field, he pioneered the design and application of many industrial installations. Mr. Zottu is chairman of the Technical Committee on Industrial Electronics of the I.R.E., a member of the committee on Industrial Heating Applications of the Radio Technical Planning Board, Induction and Dielectric Heating Committee of the American Institute of Electrical Engineers, chairman of the committee on Frequency Allocations of the Society of the Plastics Industry, member of the American Physical Society, American Association for the Advancement of Science, and Society of the Plastics Industry.

PAUL D. ZOTTU

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ALLAN R. OGILVIE

Allan R. Ogilvie (A'43) has been named a vice-president of Maguire Industries, Inc., in charge of its Bridgeport, Connecticut plant.

A native of Boston, Mr. Ogilvie studied at the Massachusetts Institute of Technology and Temple University. His first position was with the Wireless Specialty Company, after which he became affiliated with Western Electric Company. Later, Mr. Ogilvie joined the Radio Corporation of America where he was an engineer for fourteen years. He became a member of the staff of Maguire Industries, Inc., in 1944, and was chief engineer of the Company's electronics division.

D. L. JAFFE

D. L. JAFFE

D. L. Jaffe (A'37) has joined the Polarad Electronics Company of New York as a partner and general manager.

From 1937 to 1939, Dr. Jaffe performed research in frequency modulation at Columbia University, and in 1939, he joined the Columbia Broadcasting system as television engineer engaged in studio-equipment development. Dr. Jaffe was appointed development engineer in the microwave radar division of the Raytheon Manufacturing Corporation in 1942, during which time he acted as liaison engineer between that Corporation and the Radiation Laboratory at the Massachusetts Institute of Technology. He then joined the staff of the Templetone Radio Manufacturing Corporation as chief research engineer.

Dr. Jaffe is an Associate member of the American Institute of Electrical Engineers and a member of Sigma Xi.

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CLAUDE LYONS

Claude Lyons (M'27-SM'43) joint managing director of Messrs. Claude Lyons, Ltd., Liverpool and London, England, was appointed on July 5, 1945, as the first Chairman of the Federation of Anglo-American Importers, the headquarters of which are at 180 Tottenham Court Road, London, W.1, England. The Federation is a nonprofit organization open to importers into England of radio, electronic, and allied equipment; manufacturers of such equipment in the United States of America; and persons interested in the promotion of and the continued welfare of the radio, electrical, and allied industries, as well as good relationships in international commerce.

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F. C. MCMULLEN

F. C. McMullen (A'42) has been appointed chairman of the aviation section of the Radio Manuacturers Association's transmitter division, and is in charge of aviation radio sales for Western Electric Company. He succeeds J. W. Hammond (A'44–SM'45) of Bendix Radio, Baltimore, Maryland.

Peacetime Radio Production

I. J. Kaar (right) (J'22–A'24–M'29–F'41), manager of General Electric's receiver division, discusses first peacetime radio off production lines at the company's Bridgeport, Connecticut, plant, with Paul L. Chamberlain (A'43), manager of sales for the division. In background is radar console.

Manuel Fernandez

Major Manuel Fernandez (A'42–M'44), Division Communications Officer, was awarded the Bronze Star Award, it was recently announced by Brigadier General William H. Tunner, commanding general of the India China Division, Air Transport Command. The award was made for distinguishing himself by meritorious service in connection with military operations against the enemy during the period October 26, 1944 to September 2, 1945.

The citation accompanying the award adds:

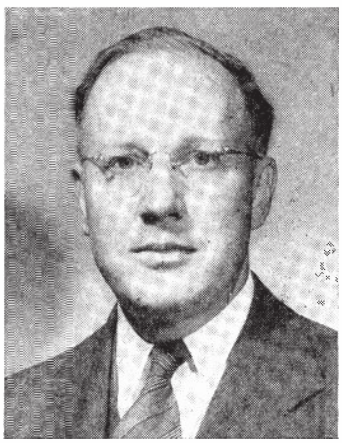
"For distinguishing himself by meritorious service as Division Communications officer, India China Division, ATC, Major Fernandez was responsible for the co-ordination of all communication facilities and activities of the India China Division. His close liaison with all those whose work showed a direct relationship to Communications and his co-ordination of all Division activities in this respect were fundamental factors in the harmonious and efficient functioning of communication matters throughout the ICD. In discharging his duties with a measure of efficiency conspicuously above the ordinary, and by his ability, aggressiveness, and perseverance in successfully coping with all problems and phases of communications under his jurisdiction, he rendered services of very great value to the India China Division, Air Transport Command."

In civilian life Major Fernandez worked in communications for Pan American Airways. He is a member of the Veteran Wireless Operators Association, Inc.

Clinton R. Hanna

Clinton R. Hanna (M'28–SM'43), inventor of the gyroscopic tank gun stabilizer which played so vital a role in the effectiveness of America's tank warfare, recently was presented for the degree of Doctor of Engineering at the eighty-first commencement exercises of Purdue University in Lafayette, Indiana.

Mr. Hanna won a Presidential Citation in 1942 for his work in the development of the tank gun stabilizer—the instrument which enabled Allied tanks to fire accurately while in motion. He has long been associated with Westinghouse engaging in and directing advanced development work on new apparatus, and has patented many of his inventions. Mr. Hanna has been engaged in research on loudspeaker equipment, on power tubes for radio receiving sets, and has developed various types of microphones, noise-measuring apparatus, methods for quieting equipment, and the development of methods of noiseless recording. In 1936, Mr. Hanna devised a gyroscopic regulator for steel-mill-roll motors, which assures that all the rolls run at the same speed, thus maintaining even tension in the steel sheet as it runs through them. Two years later, he designed an automatic voltage regulator first used for the control of generators.



Clinton R. Hanna

He was born in Indianapolis in 1899 and was graduated from Purdue University in 1922 with the degree of Bachelor of Science in electrical engineering. He enrolled immediately in the Westinghouse Graduate Student Training Course in the East Pittsburgh, Pennsylvania Works, became a research engineer for the company the following year, and received the professional degree of electrical engineer from Purdue in 1926. Four years later, he was made manager of the electromechanical department of the laboratories, and was appointed an associate director last year.

Mr. Hanna has reported on his technical experiences in numerous scientific journals. He is a Fellow of the American Institute of Electrical Engineers and of the Acoustical Society of America and a member of the Institute of Aeronautical Sciences.

Henry Grossman

Progress in the various phases of television research of the Columbia Broadcasting System, under the direction of Peter C. Goldmark (A'36–M'38–F'42), has made possible an integration of technical operations in the television field with the network's other New York broadcast operations. Accordingly, Henry Grossman (M'34–SM'43) will share in the responsibility for television technical operation routines, personnel, and routine maintenance of equipment, supplementing his previous broadcast commitments. The responsibility for equipment design and installation, engineering standards, and development tests will remain under Dr. Goldmark's direction, the latter working directly with Mr. Grossman and the technical supervisors to facilitate the application of new knowledge and new techniques.

CBS Photo

Henry Grossman

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SECTIONS

Chairman		Secretary
R. A. Holbrook 146 Lawrenceville Rd. Decatur, Ga.	ATLANTA March 15	I. M. Miles 554—14 St., N.W. Atlanta, Ga.
R. N. Harmon 1920 South Rd. Mt. Washington, Baltimore 9, Md.	BALTIMORE	F. W. Fischer 714 S. Beechfield Ave. Baltimore, Md.
C. C. Harris Tropical Radio Telegraph Co Box 584, Hingham, Mass.	BOSTON	A. G. Bousquet General Radio Co. 275 Massachusetts Ave. Cambridge 39, Mass.
A. DiMarco Carabobo 105 Buenos Aires, Argentina	BUENOS AIRES	H. Krahenbuhl Transradio Internacional San Martin 379 Buenos Aires, Argentina
J. M. Van Baalen 282 Orchard Dr. Buffalo 17, N. Y.	BUFFALO-NIAGARA February 20	H. W. Staderman 264 Loring Ave. Buffalo, N. Y.
T. A. Hunter Collins Radio Co. 855—35 St., N.E. Cedar Rapids, Iowa	CEDAR RAPIDS	R. S. Conrad Collins Radio Co. 855—35 St, N.E. Cedar Rapids, Iowa
Cullen Moore 327 Potomac Ave. Lombard, Ill.	CHICAGO March 15	D. G. Haines 4000 W. North Ave. Chicago 39, Ill.
J. D. Reid Box 67 Cincinnati 31, Ohio	CINCINNATI March 12	P. J. Konkle 5524 Hamilton Ave. Cincinnati 24, Ohio
R. A. Fox 2478 Queenston Rd. Cleveland Heights 18, Ohio	CLEVELAND February 28	Walter Widlar 1299 Bonnieview Ave. Lakewood 7, Ohio
H. W. Sundius Southern New England Telephone Co. New Haven, Conn.	CONNECTICUT VALLEY February 21 New Haven "Color Television" L. Grew	L. A. Reilly 989 Roosevelt Ave. Springfield, Mass.
R. M. Flynn Station KRLD Dallas 1, Texas	DALLAS-FT. WORTH	J. G. Rountree Box 5238 Dallas 2, Texas
L. B. Hallman 3 Crescent Blvd. Southern Hills Dayton, Ohio	DAYTON March 5 Dayton Engineers' Club (Joint Meeting) "Engineering Education" W. L. Everitt	Joseph General 411 E. Bruce Ave. Dayton 5, Ohio
H. E. Kranz International Detrola Corp. 1501 Beard Ave. Detroit 9, Mich.	DETROIT February 21	A. Friedenthal WJR Fisher Building Detroit 2, Mich.
N. L. Kiser Sylvania Electric Products, Inc. Emporium, Pa.	EMPORIUM	D. J. Knowles Sylvania Electric Products, Inc. Emporium, Pa.
H. I. Metz Civil Aeronautics Authority Experimental Station Indianapolis, Ind.	INDIANAPOLIS	V. A. Bernier 5211 E. 10 Indianapolis, Ind.
R. N. White 4800 Jefferson St. Kansas City, Mo.	KANSAS CITY	Mrs. G. L. Curtis 6003 El Monte Mission, Kansas
B. S. Graham Sparton of Canada, Ltd. London, Ont., Canada	LONDON, ONTARIO March 19	C. H. Langford Langford Radio Co. 246 Dundas St. London, Ont., Canada
Frederick Ireland General Radio Co. 1000 N. Seward St. Hollywood, Calif.	LOS ANGELES March 15	Walter Kenworth 1427 Lafayette St. San Gabriel, Calif.

PAUL J. GOLLHOFER

PAUL J. GOLLHOFER

Paul J. Gollhofer (A'44) has been appointed director of television of the Sherron Electronics Company of Brooklyn, New York. In this capacity he will be engaged in the technical phases of the work of that company and will co-operate with all persons and agencies concerned with the engineering, design, and operation of a new experimental television station W2XDK.

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J. KELLY JOHNSON

J. Kelly Johnson (A'25–M'35–SM'43) has opened an office for radio and electronic engineering consulting services at 55 West 42 Street, New York, N. Y.

Mr. Johnson, who received the graduate degree in electrical engineering from Columbia University in 1927, was an instructor in physics at the Mechanics Institute, New York, from 1925 to 1929, and an instructor in electrical engineering at Columbia from 1928 to 1929. During this latter period, he also held the position of chief research engineer at the Pacent Electrical Corporation, New York, and for the period 1929 to 1930, was assistant chief engineer at Silver-Marshall, Chicago, Illinois. Mr. Johnson then returned to New York to become an engineer with the Hazeltine Corporation. From 1934 to 1943, he was again located in Chicago, serving as chief engineer with Wells Gardner Company, and later as engineer in charge of the Chicago Laboratory of Hazeltine Service Corporation. In 1943, at the Office of the Secretary of the Navy, Washington, D. C., Mr. Johnson became chief of production section, electronics division, until 1944, when the Hammerlund Manufacturing Company, New York, named him executive engineer.

Mr. Johnson was a director of The Institute of Radio Engineers in 1942, and chairman of the Chicago Section in 1936. He is a member of the Receivers and Sections Committees of the Institute, and holds the chairmanship of the I.R.E. Papers Procurement Committee on Radio Communications. Mr. Johnson is a Fellow of the Radio Club of America, a member of the American

J. KELLY JOHNSON

Institute of Electrical Engineers and of the Radio Engineers Club of Chicago. He is also a member of the Export Receivers, Very-High-Frequency, and Receivers Executive Committees of the RMA, and of Tau Beta Pi, Sigma Xi, and Epsilon Chi.

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Books

Electronics Laboratory Manual, by Ralph R. Wright

Published (1945) by McGraw-Hill Book Co., 330 West 42 St., New York, N. Y. 77 pages+viii pages. 78 illustrations. 5½×8 inches. Price, $1.00.

This manual is designed to present 12 basic experiments "intended to acquaint the student with the characteristics, principle of operation, and applications of electron tubes."

Since the attainment of this objective is nearly impossible in 12 experiments, it becomes necessary to choose illustrative examples. The choice seems unfortunate in some instances when, for example, one finds that three of the 12 experiments are devoted to vacuum-tube amplifiers but oscillators are not mentioned at all.

Although the avowed purpose of the text is explanatory, many paragraphs seem hurried and superficial. For example, one cannot do much more than suggest the existence of a Thyratron inverter in the 11 lines of text devoted to that subject. Unfortunately, also some of the statements in the text are either inaccurate or have erroneous implications.

The inclusion of exercises and references at the end of each experiment is excellent, but the omission of precautions to be observed, circuit constants, advice on the selection of appropriate circuit elements, etc., will force the student to use the manual merely as an outline and seek much additional information from other sources.

E. D. MCARTHUR
General Electric Co.
Schenectady 5, N.Y.

	Chairman	Secretary
MONTREAL, QUEBEC March 13	L. A. W. East Canadian Pacific Railway 204 Hospital St. Montreal, Que., Canada	R. R. Desaulniers Canadian Marconi Co. Box 1690 (Place D'Armes) Montreal 1, Que., Canada
NEW YORK March 6	G. B. Hoadley 85 Livingston St. Brooklyn, N. Y.	J. T. Cimorelli RCA Victor Div. 415 S. Fifth St. Harrison, N. J.
OTTAWA, ONTARIO February 21	W. A. Steel 298 Sherwood Dr. Ottawa, Ont., Canada	L. F. Millett 33 Regent St. Ottawa, Ont., Canada
PHILADELPHIA March 7	D. B. Smith Philco Corporation Philadelphia 34, Pa.	P. M. Craig Philco Corporation Philadelphia 34, Pa.
PITTSBURGH March 11 Mellon Institute, 8 P.M. "Pulse-Time Modulation—Its Application to Multichannel Radiotelephone Systems and Multichannel Broadcasting" D. D. Grieg	J. A. Hutcheson 852 N. Meadowcroft Ave. Pittsburgh 16, Pa.	C. W. Gilbert 52 Hathaway Ct. Pittsburgh 21, Pa.
PORTLAND	C. W. Lund Rt. 4, Box 858 Portland, Ore.	L. C. White 3236 N.E. 63 Ave. Portland 13, Ore.
ROCHESTER February 21	G. R. Town Stromberg-Carlson Co. Rochester 3, N. Y.	A. E. Newlon Stromberg-Carlson Co. Rochester 3, N. Y.
ST. LOUIS February 28	B. B. Miller 2356A Lawrence St. St. Louis 10, Mo.	N. J. Zehr 1538 Bradford Ave. St. Louis 14, Mo.
SAN DIEGO	David Kalbfell 941 Rosecrans San Diego, Calif.	Clyde Tirrell U. S. Navy Radio and Sound Laboratory San Diego 52, Calif.
SAN FRANCISCO	R. V. Howard Mark Hopkins Hotel San Francisco, Calif.	Lester Reukema 2319 Oregon St. Berkeley, Calif.
SEATTLE March 14	E. H. Smith 823 E. 78 St. Seattle 5, Wash.	W. R. Hill University of Washington Seattle 5, Wash.
TORONTO, ONTARIO	F. H. R. Pounsett Research Enterprises, Ltd. Leaside, Ont., Canada	Alexander Bow 137 Oxford St. Guelph, Ont., Canada
TWIN CITIES	H. E. Hartig University of Minnesota Minneapolis, Minn.	M. R. Ludwig 315 E. 24 St. Minneapolis, Minn.
WASHINGTON March 11	F. W. Albertson Room 1111, Munsey Bldg. Washington 4, D. C.	G. P. Adair Federal Communications Commission Washington 4, D. C.
WILLIAMSPORT March 6	Harry Smithgall Sylvania Electric Products, Inc. Plant No. 1 Williamsport, Pa.	F. L. Burroughs 2030 Reed St. Williamsport 39, Pa.

SUBSECTIONS

COLUMBUS March 8	R. C. Higgy 2032 Indianola Ave. Columbus, Ohio	Warren Bauer 376 Crestview Rd. Columbus 2, Ohio
MILWAUKEE	P. B. Laeser 9410 Harding Rd. Milwaukee, Wis.	E. L. Cordes 3304 N. Oakland Ave. Milwaukee, Wis.
MONMOUTH	L. J. Giacoletto 9 Villa Pl. Eatontown, N. J.	C. D. Samuelson 5 Russel Ave. Fort Monmouth, N. J.
PRINCETON	W. C. Johnson Princeton University Princeton, N. J.	J. G. Barry Princeton University Princeton, N. J.
SOUTH BEND February 21	H. E. Ellithorn 417 Parkovash Ave. South Bend 17, Ind.	J. E. Willson WHOT, St. Joseph and Monroe Sts. South Bend, Ind.

Lehrbuch der Funktionentheorie—Volumes I and II, by Ludwig Bieberbach

Vol. I (Fourth Edition)—Published (1945) by Chelsea Publishing Co., 231 W. 29 Street, New York 1, N. Y. 320 pages+2-page index + xiv pages. 77 illustrations. 5½×8½ inches. Price, $3.25.

Vol. II (Second Edition)—Published (1945) by Chelsea Publishing Co., 231 W. 29 Street, New York 1, N. Y. 368 pages+2-page index + vi pages. 47 illustrations. 5½×8½ inches. Price, $3.25.

This is a new edition, brought out under the authority of the Alien Property Custodian, of the fourth (1934) edition of volume I, and the second (1931) edition of volume II of Bieberbach's textbook on the theory of functions of a complex variable.

The preface of the first volume states that it was written to give the student a knowledge of the fundamental concepts and theorems of the subject, and not alone from one standpoint but also the different historical methods of development. The work was intended for students of college grade with some knowledge of analytic geometry and the calculus.

In the first volume are included the subjects usual in a textbook on this subject, that is, definitions, theorems of convergence, differentiable functions, conformal mapping, integration in the complex domain, development in series, and a study of the more important types of functions individually. The treatment is restricted to analytic functions of a complex variable.

The scope of the work is wide and the treatment is thorough. However, from the standpoint of the engineer, the book suffers from a paucity of examples. This, it should be stated, is characteristic of books on this subject in general, and this book is rather better than most.

The second volume is more advanced in tone, since it has for its goal an exposition of the more recent developments of function theory. In general, the engineer will find it harder going than the first volume.

In the production of these books the publishers have succeeded in bringing out volumes well printed and of attractive size and appearance.

FREDERICK W. GROVER
Union College
Schenectady, N. Y.

Electromagnetic Engineering, Vol. 1—Fundamentals, by Ronold W. P. King

Published (1945) by the McGraw-Hill Publishing Company, 330 W. 42 Street, New York 18, New York. 568 pages+12-page index+xiv pages. 76 illustrations. 8½×5¾ inches. Price, $6.00.

This book, subtitled Fundamentals, is the first of three volumes under the general title, "Electromagnetic Engineering." The second and third volumes are to be concerned with "Antennas" and "Transmission Circuits and Wave Guides," respectively. The purpose of the present volume is to present the laws, definitions, basic equations, and some general solutions necessary for an understanding of the succeeding volumes.

There are six chapters in the present volume. The first, entitled "The Mathematical Description of Matter," is concerned with definitions of surface and volume densities of charge, convection current, polarization, and magnetization. An essential volume characteristic is defined for both the static state and the steady state. The extension of these definitions to the nonstationary state is discussed.

In Chapter II, Maxwell's field equations are presented as fundamental postulates for the mathematical model of space and simple media. The integral forms (Gauss's, Ampere's, and Faraday's laws) are derived from the fundamental equations, and the force equations are treated.

In Chapter III, the fundamental equations are transformed into a number of forms, including the forms in terms of potential functions, the complex forms for periodic time dependence, and the energy equations.

Chapter IV is concerned with waves in unbounded media and discusses wave solutions both in terms of the potentials and the electric and magnetic fields. Special attention is given the separation into near-zone or induction fields and far-zone or radiation fields, and several basic radiation problems are treated.

Chapter V discusses skin effect and internal impedance.

Chapter VI, entitled "Electric Circuits," presents the foundations of circuit theory as based upon the field equations and includes a number of articles on miscellaneous problems in mutual impedance, self-impedance, two-wire and four-wire lines. There are five appendixes and seventy-eight problems for the student.

The book is authoritative and very complete within the author's planned scope. Its most significant feature is the careful attention to detailed rigor, not only in the mathematics, but especially in the discussions of the philosophy of many aspects of electromagnetic theory. This feature will make the book attractive to a certain group of readers; it will also make difficult reading for others, for most passages require careful study and reflection and usually a certain maturity in point of view. The author states that the book is intended for graduate students and advanced seniors, but has been used for large groups of undergraduates in war-training programs. For the reasons mentioned above, the book seems more suitable for graduate students.

There are some differences between the conventions and notation of the book and those most often used in engineering literature up to this time. For example, E and B are grouped together as the fundamental field vectors with D and H as the auxiliary vectors. H is then written as νB rather than $B=\mu H$. If, as the reviewer believes, this is an arbitrary choice subject to personal preference, many will prefer the older convention, especially since the very useful transmission-line analogies of wave propagation with μ corresponding to an inductance per unit length then follow with direct correspondence. Dr. King's point is that it is not a matter of preference but of correctness or incorrectness. The vector notation used employs parentheses and brackets to distinguish between scalar and vector products in place of the dot and cross of Gibb's notation. The author is to be commended on his use of rational mks units and the engineering convention $e^{j\omega t}$ for complex sinusoids.

The use of symbols in the book will also cause differences of opinion. It is very specific so that there is a difference in notation between real scalars, complex scalars, real vectors, and complex vectors, internal and external quantities. However, this requires the use of Gothic letters as well as italics with both in ordinary and bold type. It is sometimes difficult to distinguish between certain of these, especially between ordinary and bold-face Gothic when both are not present on the same page for comparison purposes. This is also important in teaching from the book, for it is difficult to distinguish in blackboard writing between four kinds of a given letter (eight, counting lower case). Superscripts are also used as well as subscripts. The use of an asterisk both to denote conjugates of complex quantities and for certain footnote references should be noted.

"Electromagnetic Engineering," more than many books on an old subject, is characterized by an individuality both in approach and detail, and for this reason will find both supporters and critics among its readers.

J. R. WHINNERY
General Electric Co.
Schenectady, N. Y.

BERNARD A. ENGHOLM

Bernard A. Engholm (A'22-M'27-SM-'43), former president of The Rola Company, Inc., of Cleveland, Ohio, died on October 20, 1945. He was born in Ouray, Colorado, in 1899.

Mr. Engholm entered the field of radio in 1924 after developing a loudspeaker in a barn in Seattle. He took his device to a radio store in that city, and a demonstration of it resulted in a partnership in loudspeaker manufacturing. The business begun in Seattle was later moved to Oakland, California, and then to Cleveland. Mr. Engholm subsequently established The British Rola Company and The Australian Rola Company. He later relinquished his control over the Australian firm but retained an equal interest in the British company.

During World War II, Mr. Engholm developed and produced many war items and during his lifetime secured more than forty patents, all of which were assigned to his company. His interest in The Rola Company was sold by him about a month prior to his death.